Scottish Sanitary Survey Project

Sanitary Survey Report

Roe Sound (SI 334)

March 2010

Report Distribution – Roe Sound

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

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1. General Description

Roe Sound lies within St Magnus Bay, on the west coast of Shetland. It is 2.9 km in length, 0.2 km wide at its narrowest point and 0.8 km wide at its widest point. It has a south east to north west aspect, and is connected to Busta Voe to the south east by a narrow channel which runs under Muckle Roe Bridge, and opens out to St Magnus Bay at its north western end. The sound is up to 20 m deep at the northern end. This sanitary survey was undertaken in response to an application for classification of this area for common mussels.

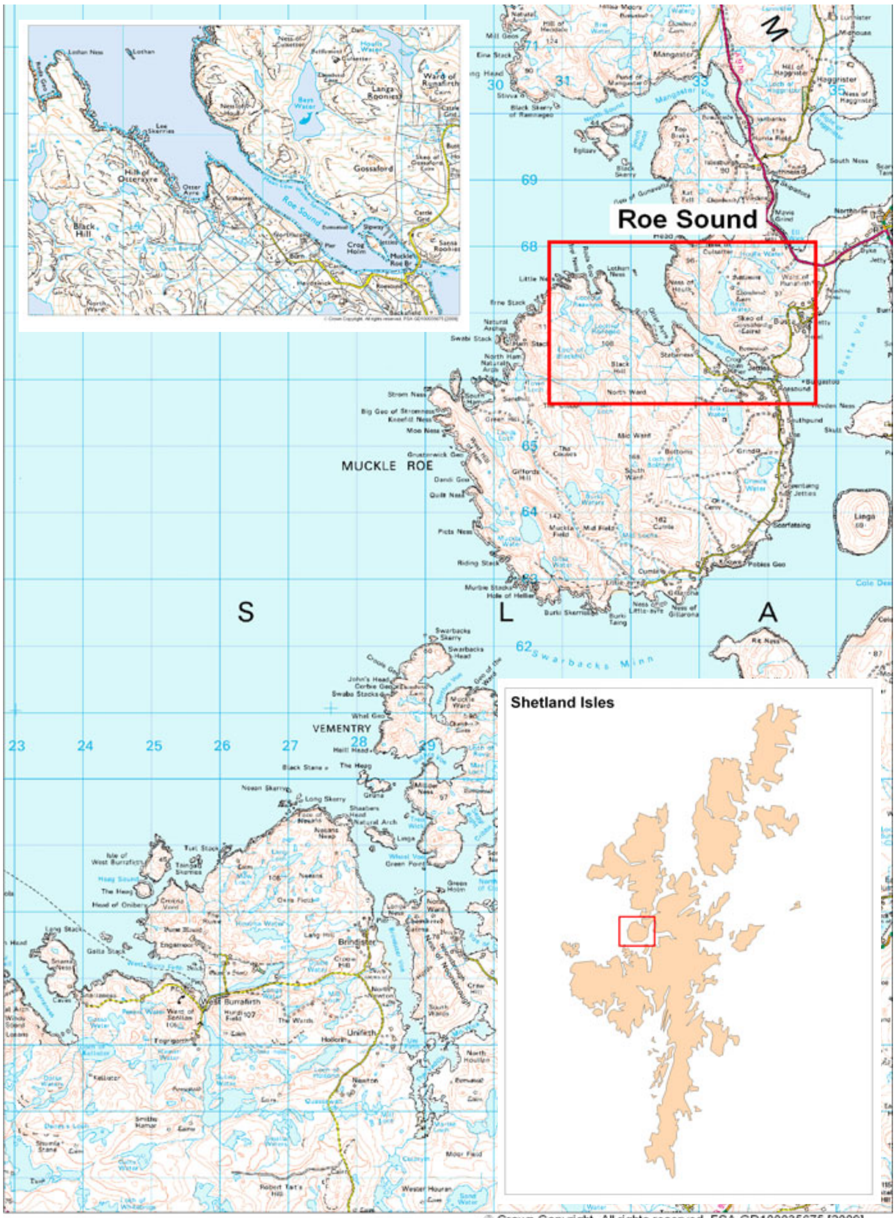

Figure 1.1 Location of Roe Sound

2. Fishery

Roe Sound was previously classified for production of common mussels but was declassified in 2008 due to insufficient provision of samples during 2007. The previous production area was defined as the area bounded by lines drawn between HU 3420 6590 and HU 3420 6605 and between HU 3165 6750 and HU 3250 6750. The Representative Monitoring Point (RMP) was assigned at HU 328 670. The Busta Voe Lee North production area, which has already been the subject of a sanitary survey (Cefas/FSAS, 2008) adjoins the south eastern end of the former Roe Sound production area.

Table 2.1 Roe Sound Shellfishery

Site	SIN	Species
Roe Sound	SI 334 715 08	Common mussel

Figure 2.1 shows the relative positions of the declassified production area, and the RMP for Roe Sound. Both the Crown Estate and Shetland Islands Council have provided map layers for seabed leases or permits related to shellfish aquaculture. For Roe Sound, the SIC permit area and the Crown Estate lease correspond so only the SIC permit area is represented in Figure 2.1.

The fishery consists of three longlines with 8 m droppers. A dedicated sampling bag is located at the south east end of the site at a depth of 6 m.

It is intended that harvest may be undertaken at any time during the year.

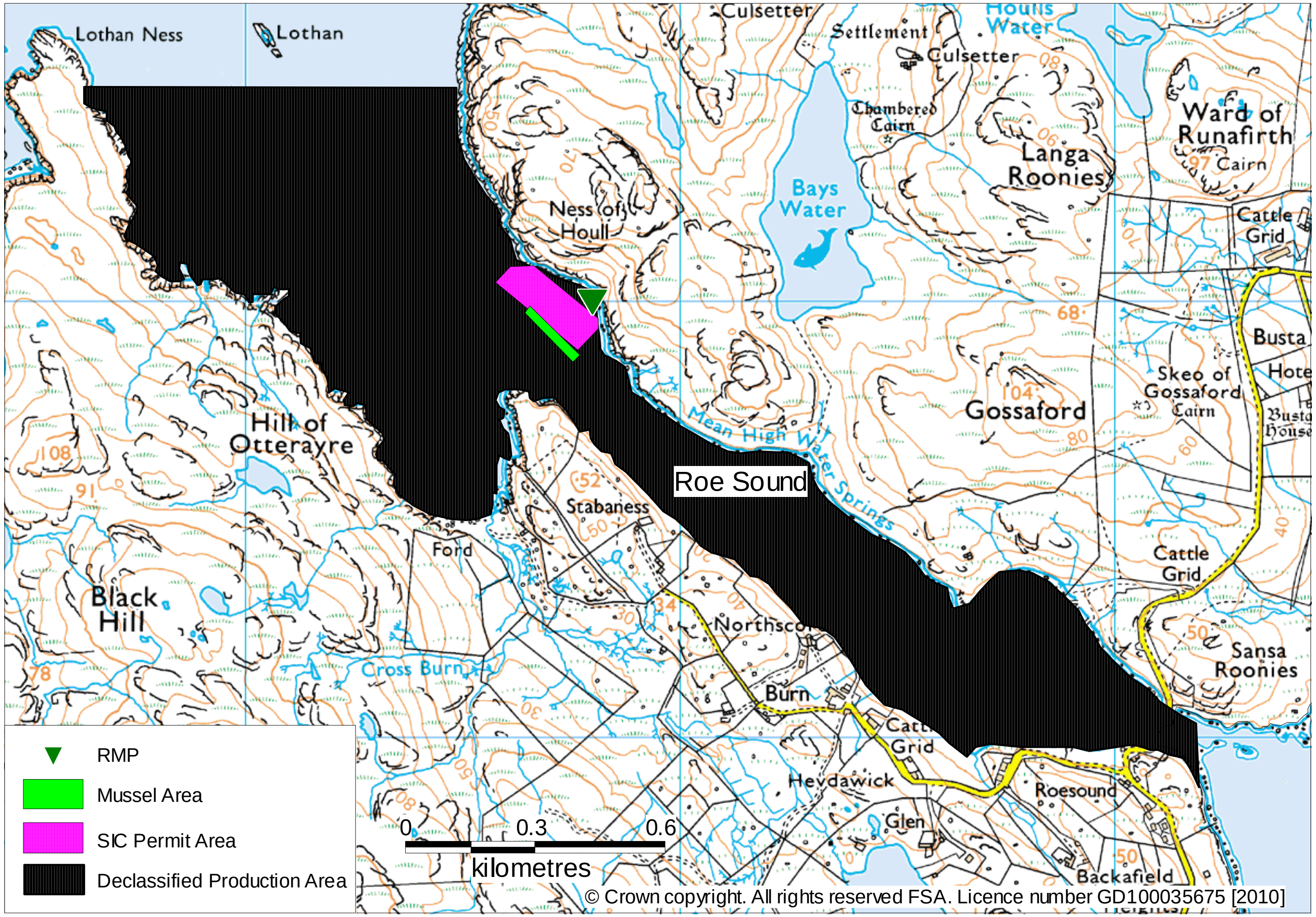

Figure 2.1 Roe Sound Fishery

3. Human Population

Figure 3.1 shows information obtained from the General Register Office for Scotland on the population within the census output areas in the vicinity of Roe Sound. The last census was undertaken in 2001.

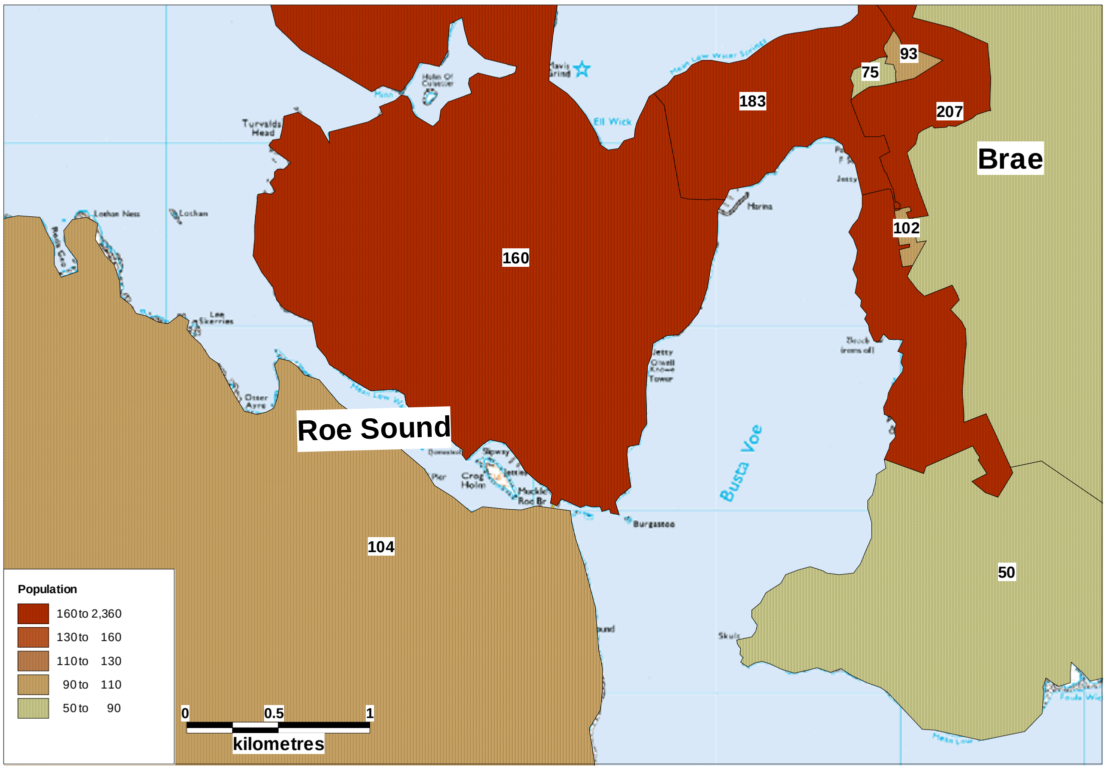

Figure 3.1 Human population surrounding Roe Sound

There are two population census areas immediately bordering Roe Sound, with populations of 104 to the south, and 160 to the north, although only a small fraction of these live on the shores of Roe Sound.

There are no settlements directly adjacent to Roe Sound. Brae is the closest village, located to the east of Busta Voe, with a total population approximately of 660. The census areas immediately surrounding Roe Sound are relatively large and sparsely populated. There are no houses shown on the Ordnance Survey map on the north shore of Roe Sound, whereas there are several on the south shore between Otter Ayre and Muckle Roe Bridge.

As population on the shore of Roe Sound is low, and there are no attractions or tourist accommodation here, it is unlikely that there is a significant increase in population during the summer months. There may be a seasonal increase in population on the shores of Busta Voe, as there is some tourist accommodation there and two marinas.

4. Sewage Discharges

No Scottish Water discharges were identified to Roe Sound. One consented discharge in the area was listed by SEPA, details of which are presented in Table 4.1.

Table 4.1 Discharges identified by SEPA

Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Consented/ design PE	Discharges to
CAR/R/1036919	HU 3374 6599	Domestic	Septic Tank		6	Roe Sound

As there has not historically been a requirement to register septic systems in Scotland, this list is unlikely to cover all septic tanks in the area. A physical survey of the shoreline was undertaken and observations of septic tanks and/or outfalls present along the shoreline are presented in Table 4.2.

Table 4.2 Discharges and septic tanks observed during shoreline survey

No.	Date	NGR	Observation	SEPA consent no.
1	27/08/2009	HU 33739 65977	Private sewer pipe, dripping 3ml/s, foul odour. Water sample 9 (1.1 x 10^7 *E. coli* cfu/100ml).	CAR/R/1036919
2	27/08/2009	HU 33412 66146	Black PVC drainage pipe, running, foam and smell of silage or brewery waste. Water sample 13 (390 *E. coli* cfu/100ml)	
3	01/09/2009	HU 33288 66049	Septic tank behind trailer home, presumably to soakaway.	

Of these, observation 1 was confirmed to be a foul discharge to Roe Sound, and its location suggests that it is the same discharge as that listed in Table 4.1. Observation 2 did not contain a significant sanitary content at the time of survey, and aligns with the path of a stream on the Ordnance Survey map so it is likely that this is a small land drain, although there were signs that the pipe may have been carrying agricultural waste as well as land runoff. Observation 3 was a septic tank which presumably discharges to soakaway and so should not have any affect on water quality within Roe Sound assuming it is functioning correctly. Therefore, there is only one known sewage discharge direct to Roe Sound, which is a small private septic tank discharge that lies just over 1.3 km from the fishery.

A small marina is located on the north shore of Roe Sound, just to the west of Muckle Roe Bridge where there is space for about 30 small boats. None seen at the time of the shoreline survey appeared to be of sufficient size to have on board toilets. There is a pier on the opposite shore here where a larger fishing boat was seen during the shoreline survey, and there is likely to be traffic associated with a salmon farm which lies within Roe Sound. It is uncertain whether these boats discharge waste water within Roe Sound.

To the east of Muckle Roe Bridge lies Busta Voe, with the settlement of Brae at its head. At Brae, there is a Scottish Water septic tank discharge designed to serve a population of 1000, as well as some other smaller private discharges and two marinas (FSAS, 2008). Therefore it is likely that water in Busta Voe is subject to higher levels of contamination than Roe Sound itself, and the open water of St Magnus Bay at the other end of Roe Sound. Therefore higher levels of contamination may be expected when the tidal stream carries water from Busta Voe into Roe Sound.

Therefore, it is concluded that sewage inputs to Roe Sound are minimal, and unlikely to significantly impact on the fishery, although contamination from sewage discharges within Busta Voe may make a significant contribution to levels of contamination found within Roe Sound. Any effect of the latter would be expected to be greater at the south-eastern end of the lines.

Figure 4.1 Known and potential sewage discharges at Roe Sound

5. Geology and Soils

Geology and soil types were assessed following the method described in Appendix 3. A map of the resulting soil drainage classes is shown in Figure 5.1. Areas shaded red indicate poorly draining soils.

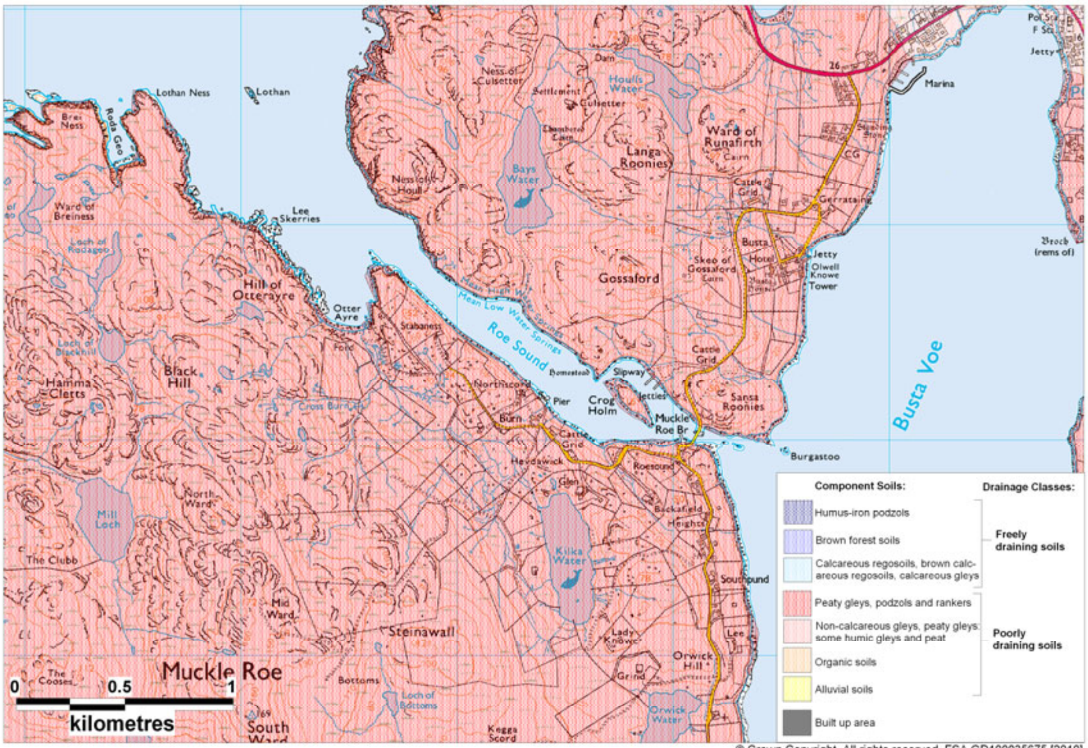

Figure 5.1 Component soils and drainage classes for Roe Sound

One type of component soil dominates the area: peaty gleys, podzols and rankers and organic soils. These soils are poorly draining. Therefore, the potential for runoff contaminated with *E. coli* from human and/or animal waste is high for all the land surrounding Roe Sound.

6. Land Cover

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

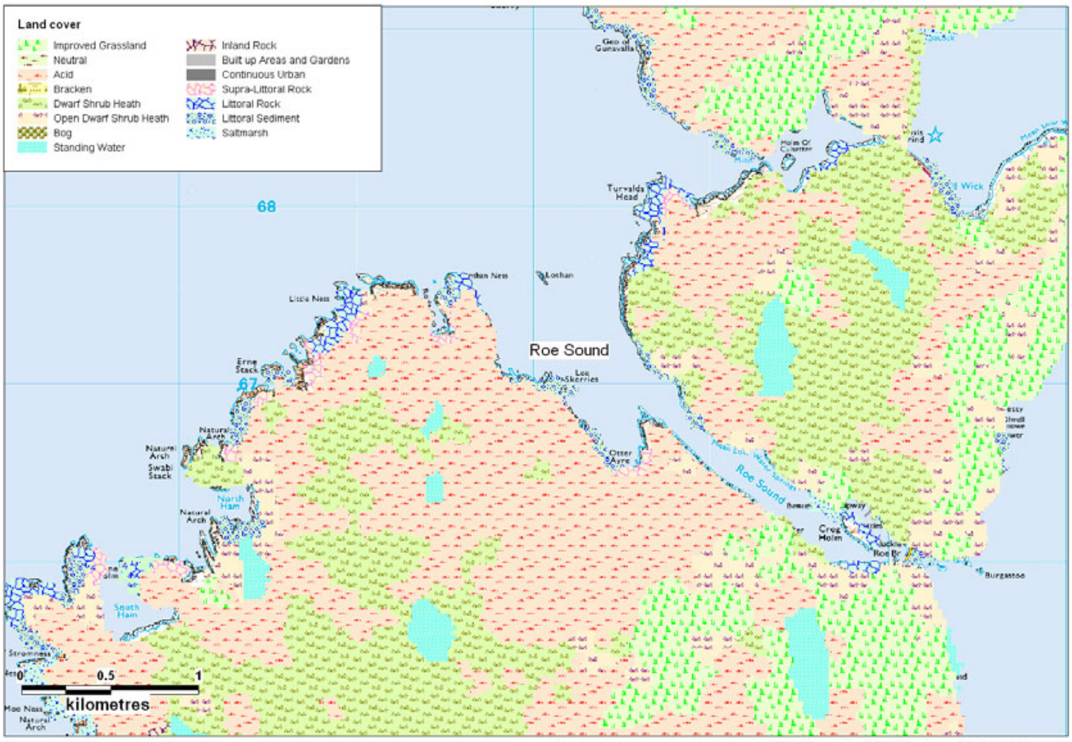

Figure 6.1 LCM2000 class land cover data for Roe Sound

There are three main types of land cover shown in Figure 6.1: acid grassland, improved grassland and dwarf shrub heath. There are also areas on inland water and patches of saltmarsh and littoral rock along the shoreline. The areas of improved grassland are concentrated at the south eastern end of Roe Sound.

The faecal coliform contribution would be expected to be highest from developed areas (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.

Therefore, the overall predicted contribution of contaminated runoff from these land cover types would be low to intermediate, and would be expected to increase significantly following rainfall events. It is likely that the south eastern end of Roe Sound is subject to higher levels of contamination as there is some improved grassland there.

7. Farm Animals

Agricultural census data was provided by the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for the parish of Delting, encompassing a land area of 148 km^2. Reported livestock populations for 2007 and 2008 are listed in Table 7.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reporting would have made it possible to discern individual farm data. Any entries which relate to less than five holdings, or where two or fewer holdings account for 85% or more of the information, is replaced with an asterisk.

Table 7.1 Livestock numbers in Delting in 2007 and 2008

	2007		2008	
	Holdings	Numbers	Holdings	Numbers
Pigs	*	*	*	*
Poultry	13	232	14	211
Cattle	11	315	11	369
Sheep	66	27742	65	22644
Horses and ponies	*	*	5	27

* Data withheld for reasons of confidentiality

Livestock kept within these parishes is predominantly sheep. Due to the very large area of this parish, this data does not provide information on the livestock numbers in the area immediately surrounding the production areas. The only significant source of local information was therefore the shoreline survey (see Appendix), which only relates to the time of the site visit on 27th August and 1st September 2009. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1. This information should be treated with caution, as it applies only to the survey dates and is dependent upon the point of view of the observer (some animals may have been obscured from view by the terrain).

The shoreline survey confirmed that agriculture in the area is dominated by sheep, with some cattle also, although the cattle were heard but not seen. The majority of animals were observed on the south shore of Roe Sound, with highest densities at the eastern end by Muckle Roe Bridge so it is likely that the south shore is more heavily impacted by these. Contamination from livestock will primarily be carried into Roe Sound by land runoff, although direct deposition to the intertidal area may also be of significance where animals are not fenced off from the shore. Although no livestock were seen on the fields surrounding the stream that drains into Otter Ayre, large numbers of sheep droppings were found near where this stream discharges into Roe Sound.

Significant numbers of sheep and some cattle are grazed around Busta Voe (Cefas/FSAS, 2008) so contamination from these may be carried into Roe Sound by the tides.

Numbers of sheep and cattle will increase in the spring following the birth of lambs and calves, and decrease in the autumn when they are sent to market.

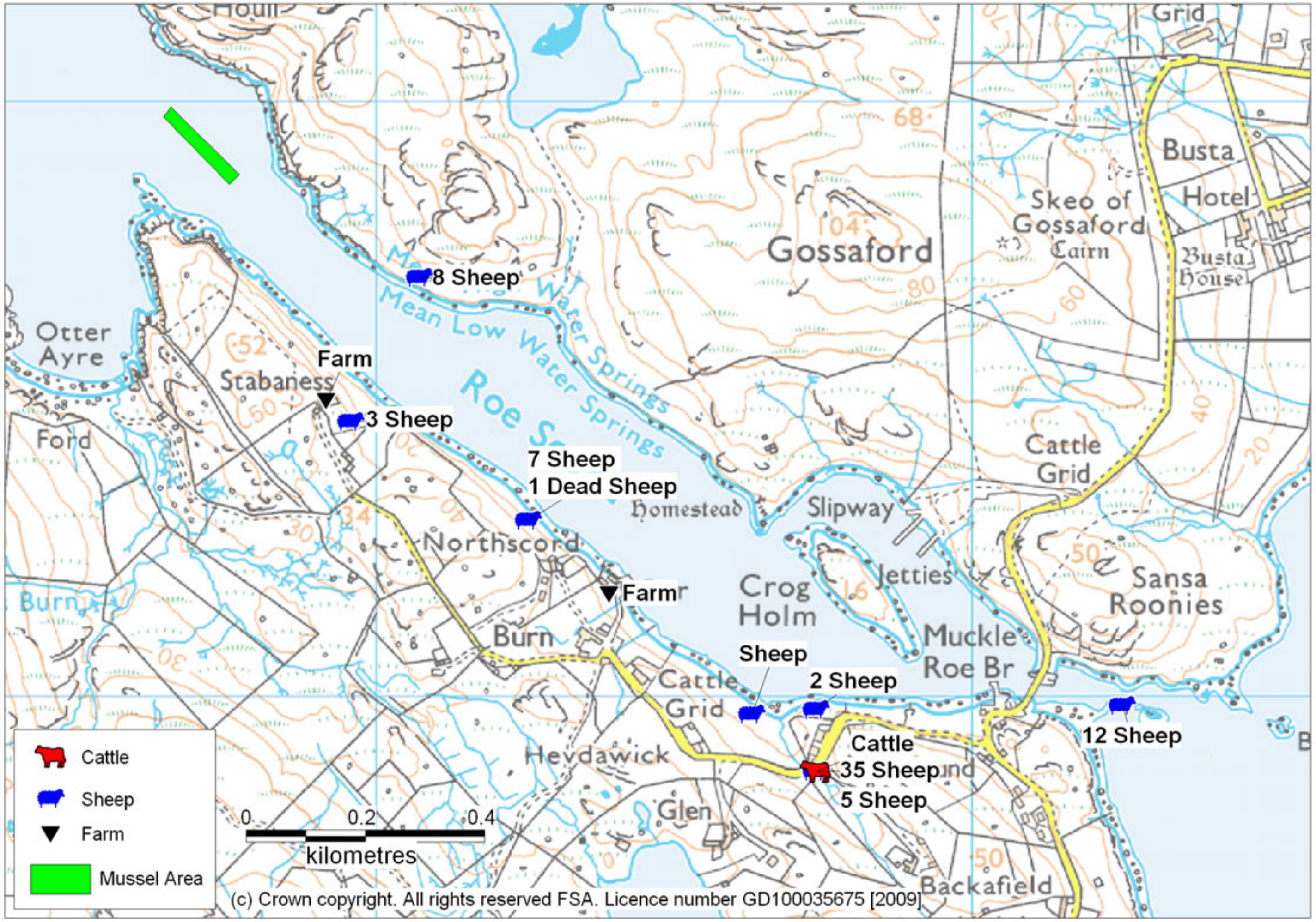

Figure 7.1 Livestock in Roe Sound observed in the shoreline survey

8. Wildlife

General information related to potential risks to water quality by wildlife can be found in Appendix 4. A number of wildlife species present or likely to be present at Roe Sound could potentially affect water quality around the fisheries.

Seals

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*). Scotland hosts significant populations of both species.

A survey conducted by the Sea Mammal Research Unit in 2001 estimated a population of 856 common seals in St Magnus Bay (SMRU, 2002). The closest haulout site identified during this survey was on the west coast of Muckle Roe.

Minimum grey seal pup production in Shetland was estimated as 943 in 2004. Adult numbers are estimated to be 3.5 times the pup population (Callan Duck, Sea Mammal Research Unit, personal communication). The closest identified breeding colony was at Muckle Roe (exact location unspecified). Pup production here was estimated at 23 in 2004.

Therefore it is likely that both species of seals regularly frequent the area. During the shoreline survey, one seal (species uncertain) was seen in the water just off the south shore of Roe Sound.

Whales/Dolphins

A variety of whales and dolphins are routinely observed near Shetland. It is possible that cetaceans will be found in the area from time to time, although the larger species will not visit this area as it is fairly shallow and enclosed. Any impact of their presence is likely to be fleeting and unpredictable.

Birds

A number of bird species are found around Roe Sound, but seabirds and waterfowl may be expected to occur around or near the fisheries. A number of seabird species breed in Shetland. These were the subject of a detailed census carried out in sections during the late spring of 1998, 1999, 2000 and 2002 (Mitchell *et al*, 2004). Total counts of all species recorded within 5 km of the mussel lines are presented in Table 8.1. Where counts are of pairs of birds, the actual number of breeding adults will be double. This data is also thematically mapped in Figure 8.1: each pair is included as two birds in the represented counts.

Figure 8.1 Breeding seabird numbers within 5 km of the fishery

Table 8.1 Counts of breeding seabirds within 5 km of the fishery

Common name	Species	Count	Method	Individual / pair
Northern Fulmar	*Fulmarus glacialis*	4142	Occupied sites	pairs
Black Guillemot	*Cepphus grylle*	601	Individuals on land	individuals
Arctic Tern	*Sterna paradisaea*	556	Occupied territory	pairs
Kittiwake	*Rissa tridactyla*	134	Occupied nests	pairs
Herring Gull	*Larus argentatus*	91	Occupied nests/territories	pairs
European Shag	*Phalacrocorax aristotelis*	89	Occupied nests/sites	pairs
Great Black-backed Gull	*Larus marinus*	57	Occupied nests/territories	pairs
Great Cormorant	*Phalacrocorax carbo*	56	Occupied nests	pairs
Common Gull	*Larus canus*	55	Occupied nests/territories	pairs
Atlantic puffin	*Fratercula arctica*	46	Occupied burrows	pairs
Black-headed Gull	*Larus ridibundus*	25	Occupied territory	pairs
Great Skua	*Stercorarius skua*	19	Occupied territory	pairs
Lesser Black-backed Gull	*Larus fuscus*	5	Occupied nests/territories	pairs
Common Tern	*Sterna hirundo*	5	Occupied territory	pairs

The seabird census indicated a high density of breeding seabirds in the general area. Over 3500 pairs were recorded on Muckle Roe, mainly along the cliffs on the west shore. Along the shores of Roe Sound itself over 600 pairs were recorded which were widely distributed in the area. Contamination of the production area from these birds would be via direct deposition as they forage, and through runoff from streams draining the areas in which they nest. Therefore impacts from these species may be expected to peak during the summer breeding season, although some species are likely to be resident year round, and would be widely spread around the area. Some gulls and other seabirds were recorded during the shoreline survey, but not in great numbers. Some were resting on the mussel floats indicating a significant potential for direct contamination of the fishery. There is no evidence to suggest they favour any particular part of the fishery as a resting place.

Waterfowl may be present in the area at various times, either to overwinter, or briefly during migration, or possibly to breed during the summer. None was seen during the course of the shoreline survey however.

Wading birds would be concentrated on intertidal areas, but no aggregations were noted during the shoreline survey.

Otters

It is likely that otters are resident in the area, although none was seen during the shoreline survey. However, the typical population densities of coastal otters are low and their impacts on the shellfishery are expected to be very minor.

Summary

In summary, the main wildlife species potentially impacting on the production areas are seabirds and seals. Large numbers of seabirds breed on Muckle Roe, including all along the shores adjacent to Roe Sound. Seabirds were observed resting on the mussel floats, so there is significant potential for contamination of the fishery by direct deposition here. Numbers are likely to be highest during the breeding season, although some species will be resident in the area year round. There are significant seal colonies within St Magnus Bay, and one individual was seen within Roe Sound, so it is likely that they are a regular presence in the area. However, as these animals are highly mobile, the impacts of these on the fishery will be unpredictable, and deposition of faeces by wildlife is likely to be widely distributed around the area.

9. Meteorological data

The nearest weather station is located at Lerwick, approximately 30 km to the south-east of the fishery, for which rainfall and wind data is available for 2003-2008 inclusive. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2008 (total daily rainfall in mm). It is likely that overall wind patterns are broadly similar at the fishery and at Lerwick, but local topography is likely to skew these patterns in different ways, and conditions at any given time may differ due to the distance between them. This section aims to describe the local rain and wind patterns and how they may affect the bacterial quality of shellfish within Roe Sound.

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 and 9.2 present box and whisker plots summarising the distribution of individual daily rainfall values by year and by month. The grey box represents the middle 50% of the observations, with the median at the midline. The whiskers extend to the largest or smallest observations up to 1.5 times the box height above or below the box. Individual observations falling outside the box and whiskers are represented by the symbol *.

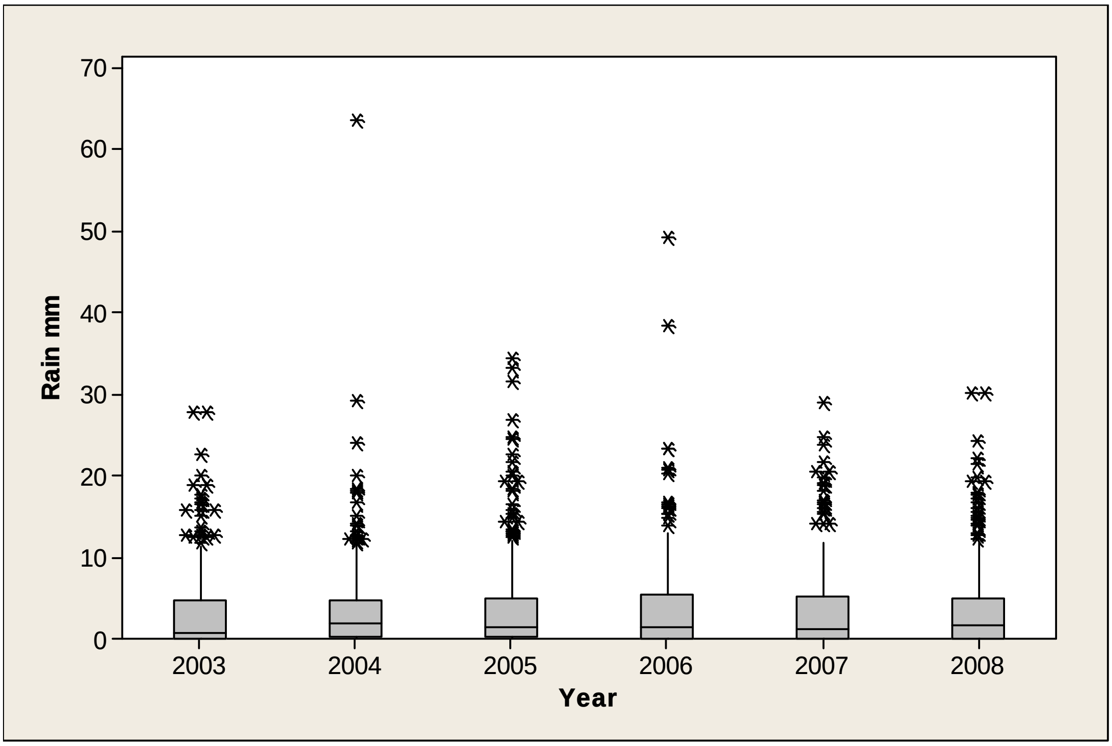

Figure 9.1 Box plot of daily rainfall values by year at Lerwick, 2003-2008

Figure 9.1 shows that rainfall patterns were generally similar between the years presented here. Total rainfall was lowest in 2003 and highest in 2006.

Extreme rainfall events (40 mm or more per day) were seen in 2004 and 2006.

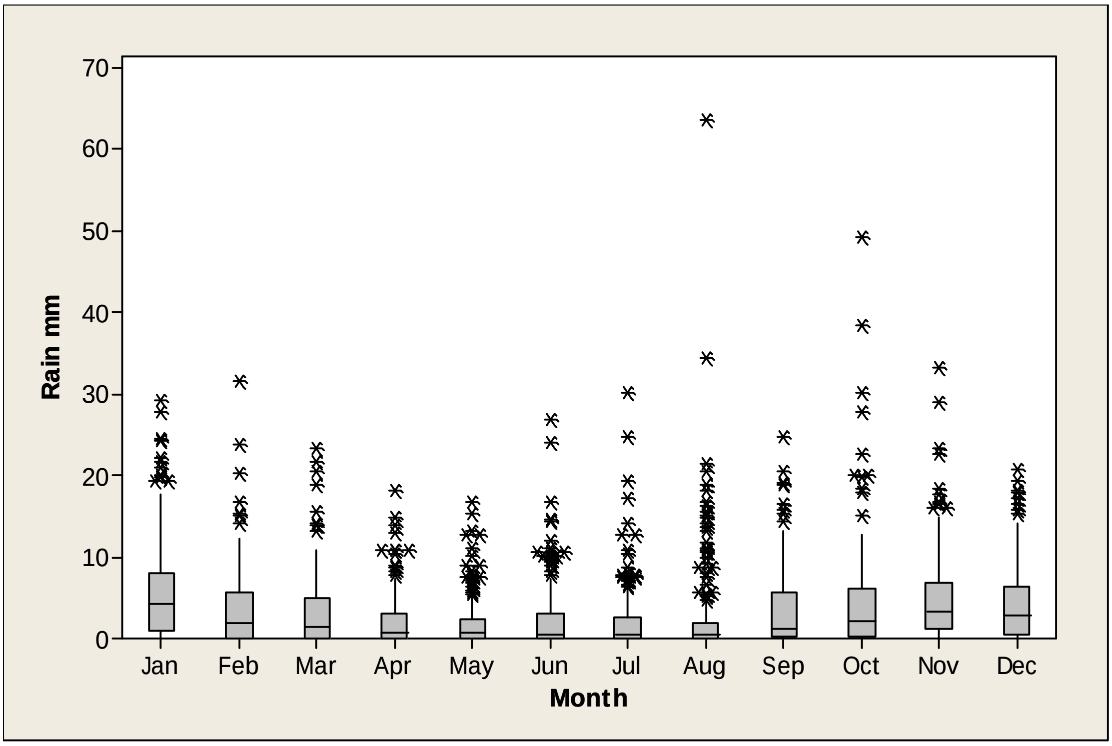

Figure 9.2 Box plot of daily rainfall values by month at Lerwick, 2003-2008

The wettest months were from September to February. April to August were the driest months. Days with high rainfall can occur at any time of the year, although the very wettest days occurred in August and October. The latter related to the events noted in 2004 and 2006. For the period considered here (2003-2008), 44% of days experienced rainfall less than 1 mm, and 9% of days experienced rainfall of 10 mm or more.

It can therefore be expected that levels of rainfall dependent faecal contamination entering the production area from these sources will be higher on average during the autumn and winter months. High rainfall events can occur at any time of year, perhaps with the exception of April and May, and these may result in a ‘first flush’ of highly contaminated runoff from pastures. This effect may be particularly acute during the summer, when livestock numbers are likely to be highest, and any preceding dry periods result in a buildup of faecal contamination on pastures.

9.2 Wind

Wind data collected at the Lerwick weather station is summarised by season and presented in Figures 9.3 to 9.7. . All wind rose figures were supplied by the Meteorological Office under license.

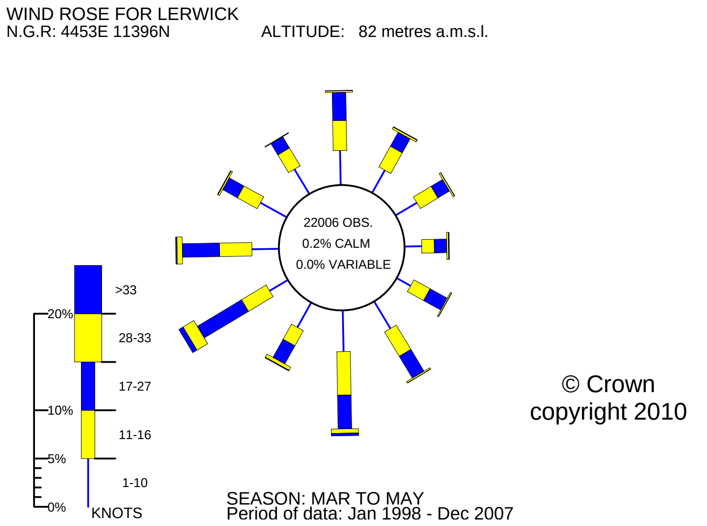

Figure 9.3 Wind rose for Lerwick (March to May)

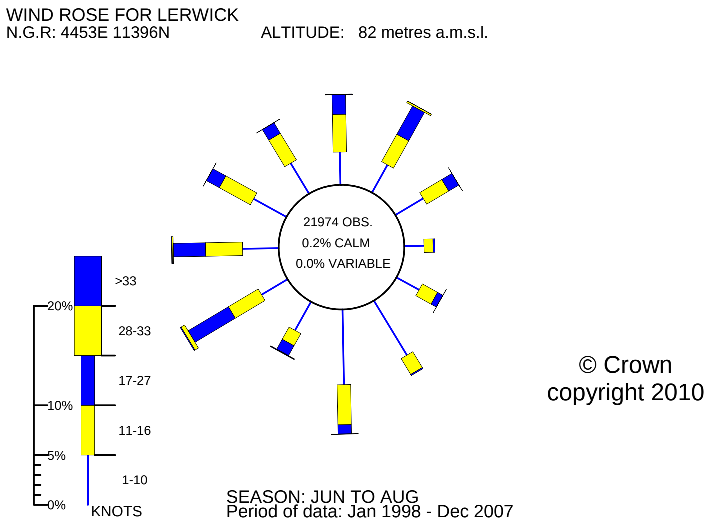

Figure 9.4 Wind rose for Lerwick (June to August)

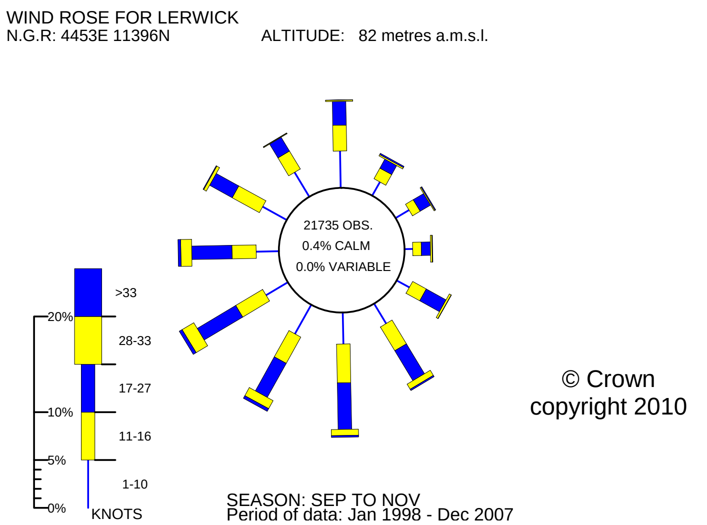

Figure 9.5 Wind rose for Lerwick (September to November)

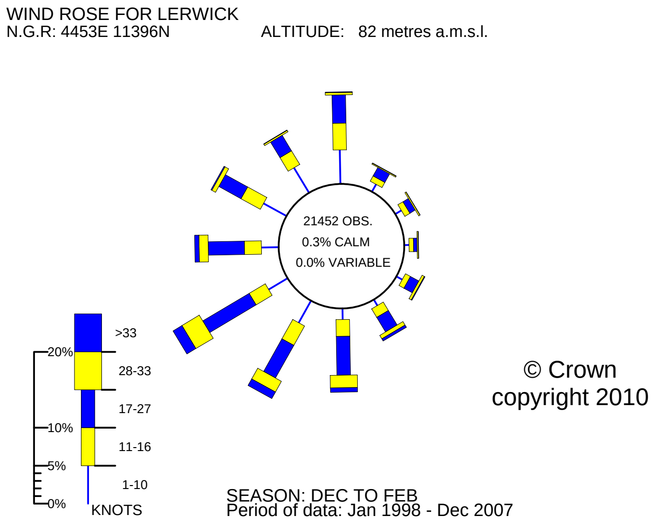

Figure 9.6 Wind rose for Lerwick (December to February)

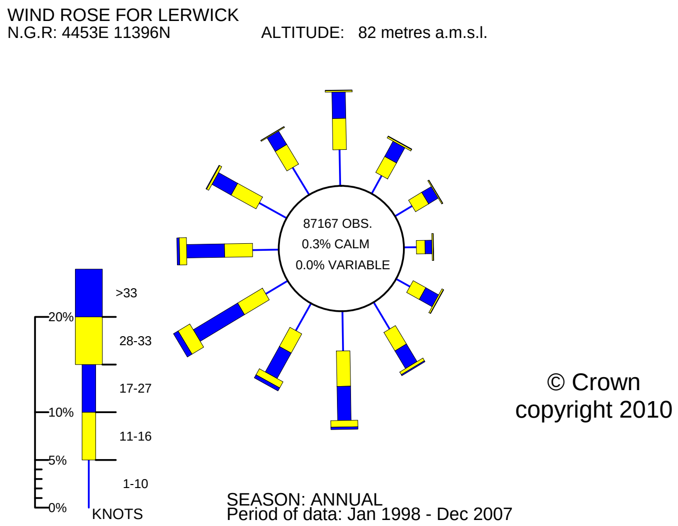

Figure 9.7 Wind rose for Lerwick (Annual)

Shetland has a much higher frequency of gales than the Scotland 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.

Roe Sound has a south-east to north-west aspect, facing the open Atlantic to the north west, with the surrounding land rising to over 150 m in places. Therefore, it is most exposed to winds from the north-west and to a lesser extent the south-east, so wind patterns here are likely to align more along this axis that they do at Lerwick. 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 which may travel along the bottom or sides of the water body depending on bathymetry. Strong winds will increase the circulation of water and hence dilution of contamination from point sources within the sound.

10. Current and historical classification status

Roe Sound was classified for the harvest of mussels from 2006 to 2007/8. Its classification history presented in Table 10.1. A map of the current production area can be found in Section 2, Figure 2.1. It was declassified in 2008/9 and no samples were submitted during 2008.

Table 10.1 Classification history, Roe Sound, common mussels

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

The area received seasonal A/B classifications, with the timing of varying between the two years although the period from May to August held A classifications in both years.

11. Historical *E. coli* data

11.1 Validation of historical data

All shellfish samples taken Roe Sound from the beginning of 2002 up to the 29th September 2009 were extracted from the database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. Two samples had invalid laboratory results so could not be used in the analysis. Five samples had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation. All *E. coli* results are reported in most probable number per 100g of shellfish flesh and intravalvular fluid.

11.2 Summary of microbiological results

A summary of all sampling and results is presented below. No samples were submitted during 2008. Two additional samples were submitted for 2009 after this statistical analysis was undertaken, both of which were below 230 *E.coli* MPN/100 g.

Table 11.1 Summary of historical sampling and results

Sampling Summary	
Production area	Roe Sound
Site	Ness of Hull
Species	Common mussels
SIN	SI-334-715-08
Location	HU328670
Total no of samples	18
No. 2005	7
No. 2006	7
No. 2007	1
No. 2008	0
No. 2009	3
Results Summary	
Minimum	<20
Maximum	1750
Median	30
Geometric mean	47.8
90 percentile	727
95 percentile	1710
No. exceeding 230/100g	3 (17%)
No. exceeding 1000/100g	2 (11%)
No. exceeding 4600/100g	0 (0%)
No. exceeding 18000/100g	0 (0%)

11.3 Overall geographical pattern of results

As all samples were reported from the same location, no assessment could be undertaken of geographic patterns in levels of *E. coli* in mussels at Roe Sound.

11.4 Overall temporal pattern of results

Figure 11.1 presents a scatter plot of individual results against date. It was not pertinent to fit any trend lines to this plot due to the low overall numbers of samples. No obvious trends were apparent.

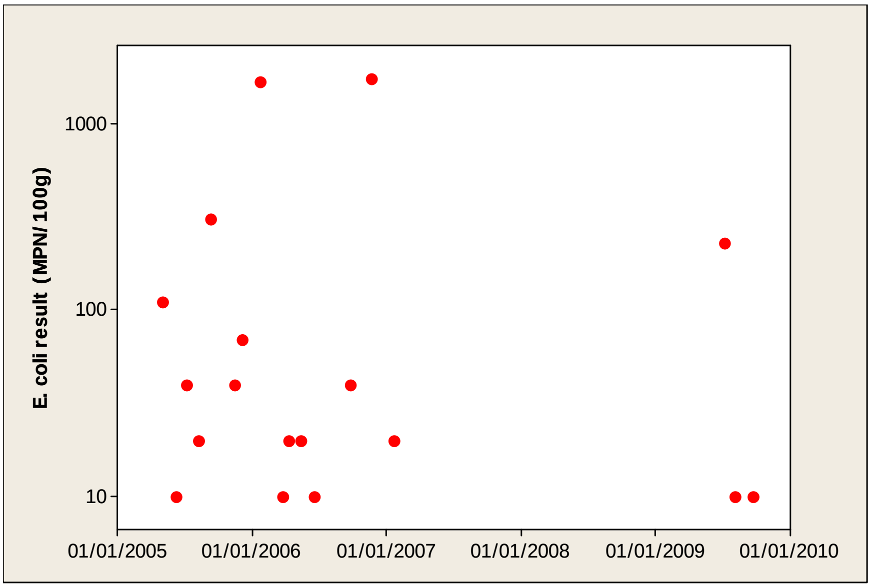

Figure 11.1 Scatterplot of *E. coli* results by date

11.5 Seasonal pattern of results

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns of human occupation. All of these can affect levels of microbial contamination, and cause seasonal patterns in results. There were too few samples to present an analysis of results by month of collection. Instead, samples were allocated to the following seasons: spring (March - May), summer (June - August), autumn (September - November) and winter (December - February).

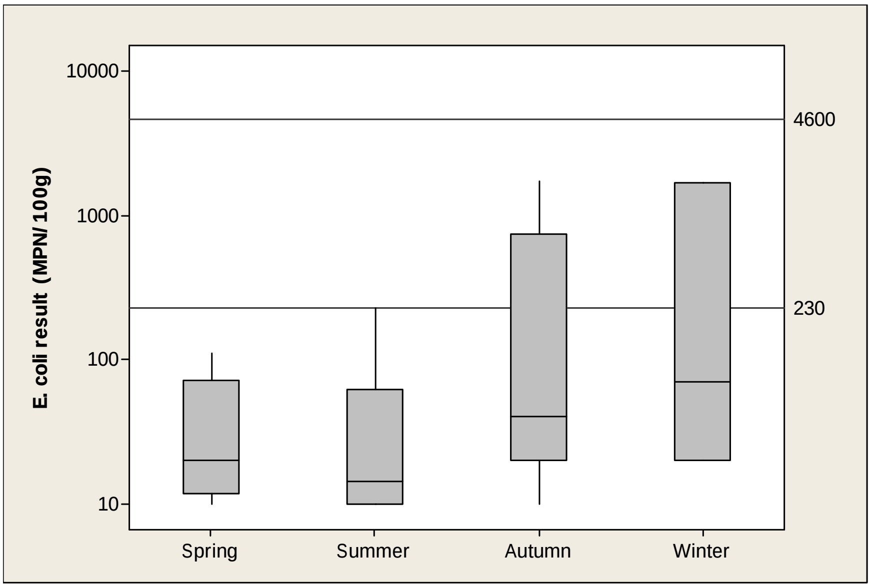

Figure 11.2 Boxplot of result by season

Although Figure 11.2 shows that higher results occurred during the autumn and winter compared to the spring and summer, no statistically significant difference was found between results by season (One-way ANOVA, p=0.329, Appendix 6). However, all three results above 230 *E. coli* MPN/100 g occurred during the autumn and winter.

11.6 Analysis of results against environmental factors

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

11.6.1 Analysis of results by recent rainfall

A comparison between shellfish *E. coli* results and both 2-day and 7-day antecedent rainfall was carried out using Spearman's Rank correlation to determine whether bacteriological results were related in any way to rainfall. The nearest weather station for which rainfall data were available was at Lerwick, approximately 30 km to the south-east of the fishery. This is a significant distance from the fishery and rainfall patterns can be assumed to differ somewhat between the two locations. As the effects of heavy rain may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationships between rainfall in the previous 2 and 7 days and sample results were investigated and are presented below.

Two-day antecedent rainfall

Figure 11.3 presents a scatterplot of *E. coli* results against rainfall recorded during the two days prior to sampling.

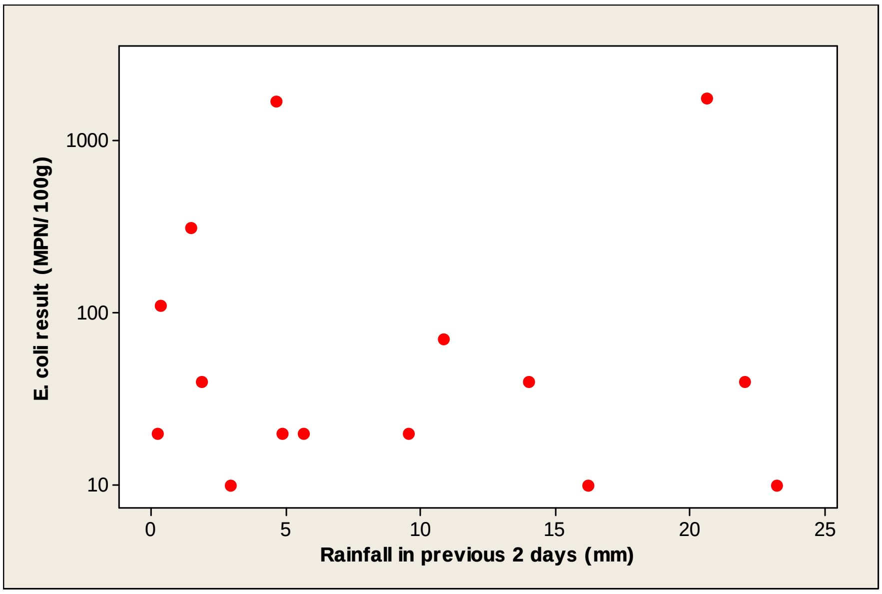

Figure 11.3 Scatterplot of result against rainfall in previous 2 days

No correlation was found between *E. coli* result and rainfall in the previous 2 days (Spearman's rank correlation=-0.165, p=0.556, Appendix 6). It can be seen, however, that the two highest *E. coli* results occurred after rainfall although the amounts varied greatly.

Seven-day antecedent rainfall

Figure 11.4 presents a scatterplot of *E. coli* results against rainfall recorded during the seven days prior to sampling.

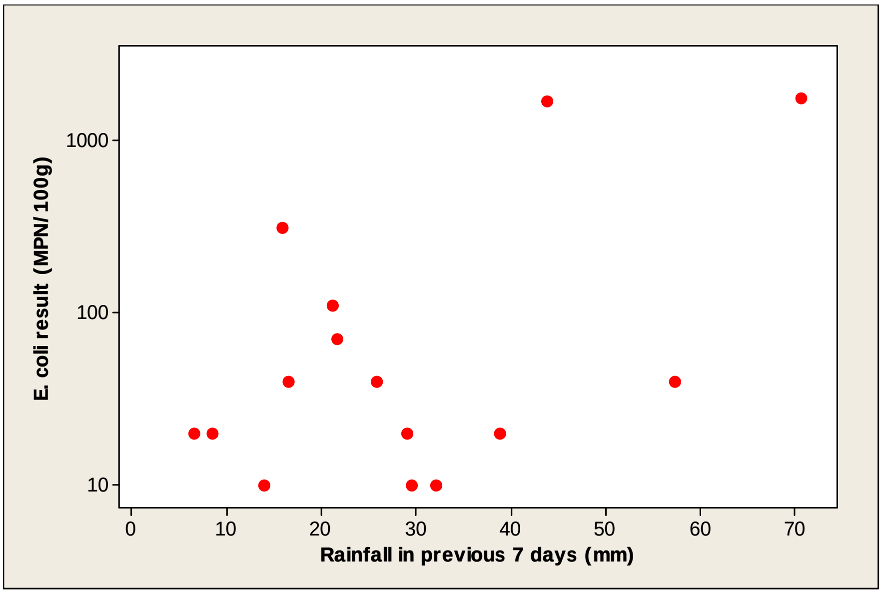

Figure 11.4 Scatterplot of result against rainfall in previous 7 days

No correlation was found between *E. coli* result and rainfall in the previous 7 days (Spearman's rank correlation= 0.258, p=0.354, Appendix 6). In this case, the two highest *E. coli* results were both seen after relatively high rainfall in the preceding seven days (see also Section 11.7).

11.6.2 Analysis of results by tidal height and state

When the larger (spring) tides occur every two weeks, circulation of water and particle transport distances will increase, and more of the shoreline will be covered at high water, potentially washing more faecal contamination from livestock into the loch. Figure 11.5 presents a polar plot of $\log_{10}$ *E. coli* results on the lunar spring/neap tidal cycle. Full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of under 230 *E. coli* MPN/100 g are plotted in green, those over 230 *E. coli* MPN/100 g are plotted in yellow. It should be noted that local meteorological conditions such as wind strength and direction can influence the height of tides and this is not taken into account.

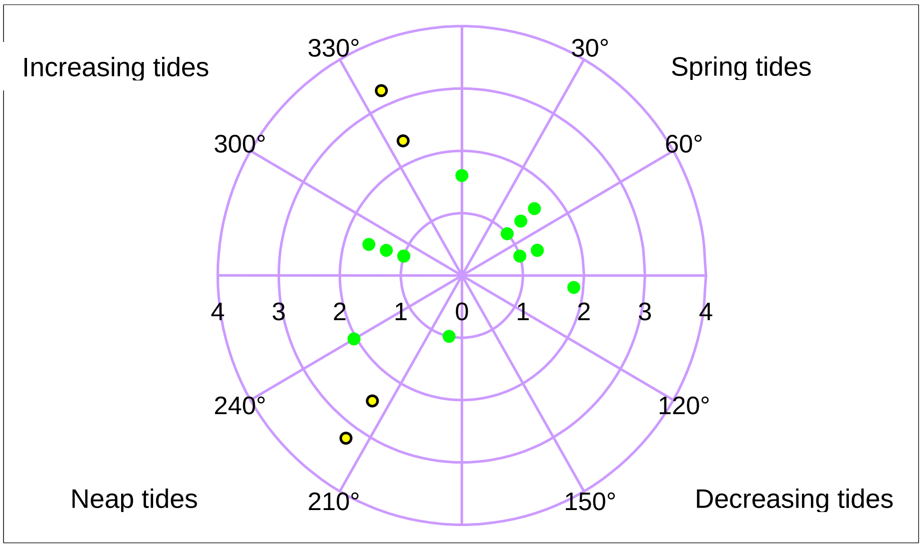

Figure 11.5 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle

No correlation was found between *E. coli* results and the spring/neap cycle (circular-linear correlation, r=0.298, p=0.262, Appendix 6), but it must be noted that sample numbers were low.

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the farms during this cycle. As *E. coli* levels in some shellfish species can respond within a few hours or less to changes in *E. coli* levels in water, tidal state at time of sampling (hours post high water) was compared with *E. coli* results. Figure 11.6 presents a polar plot of $\log_{10}$ *E. coli* results on the lunar high/low tidal cycle. High water is at 0º, and low water is at 180º. Again, results of under 230 *E. coli* MPN/100 g are plotted in green, those between 230 and 1000 *E. coli* MPN/100 g are plotted in yellow, and those over 1000 *E. coli* MPN/100 g are plotted in red.

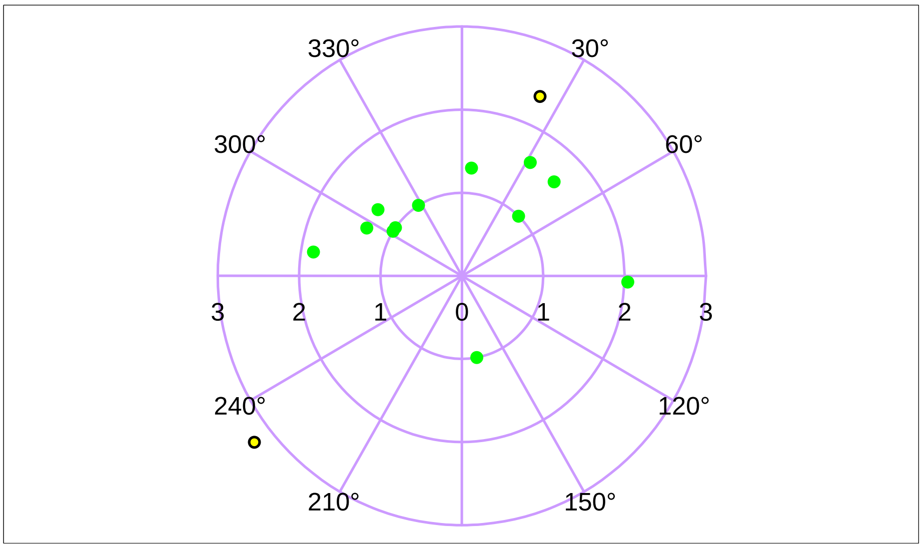

Figure 11.6 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle

No correlation was found between *E. coli* results and the high/low tidal cycle (circular-linear correlation, r=0.331, p=0.297, Appendix 6) but it must be noted that sample numbers were low.

11.6.3 Analysis of results by water temperature

Water temperature is likely to affect the survival time of bacteria in seawater (Burkhardt *et al*, 2000) and the feeding and elimination rates of shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. It is of course closely related to season, and so any correlation between temperatures and *E. coli* levels in shellfish flesh may not be directly attributable to temperature, but to other factors such as seasonal differences in livestock grazing patterns. However, water temperature was only recorded on three sampling occasions at Roe Sound, so it was not possible to assess the effects of water temperature on levels of *E. coli* in mussels.

11.6.4 Analysis of results by wind direction

Wind speed and direction are likely to change water circulation patterns within the production area. However, the nearest wind station for which records were available was Lerwick, approximately 30 km to the south-east of the fishery. Given the differences in local topography and distance between the two it is likely that the overall patterns of wind direction differ, and that the wind strength and direction may differ significantly at any given time. Therefore it was not considered appropriate to compare *E. coli* results at Roe Sound with wind readings taken at Lerwick.

11.6.5 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence, and hence freshwater borne contamination at the site. Figure 11.7 presents a scatter plots of *E. coli* result against salinity. Two of the salinity readings were over 36 ppt, outside of the normal range expected, so were not used in the analysis.

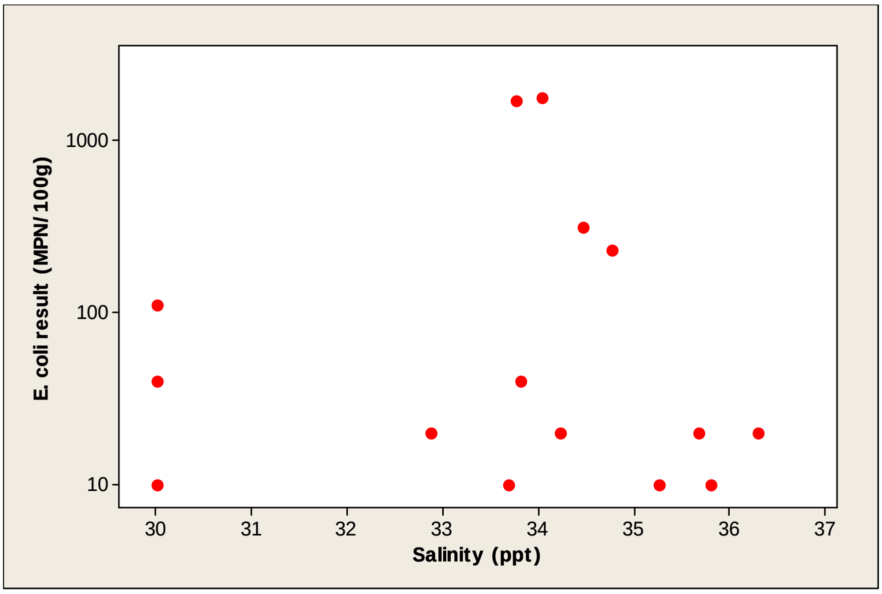

Figure 11.7 Scatterplot of result by salinity

The coefficient of determination indicated that there was no relationship between the *E. coli* results in mussels and salinity (Adjusted R-sq=0.0%, p=0.921, Appendix 6).

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

A total of 3 samples gave a result of over 230 *E. coli* MPN/100g, and these are listed in Table 11.2.

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

Collection date	Location	*E. coli* (MPN/100g)	2 day rainfall (mm)	7 day rainfall (mm)	Salinity (ppt)	Tidal state (high/low)	Tidal state (spring/neap)
12/09/2005	HU328670	310	1.4	15.8	34.47	*	Neap
23/01/2006	HU328670	1700	4.6	43.8	33.76	*	Neap
19/11/2006	HU328670	1750	20.6	70.6	34.04	Flooding	Increasing to spring

* Data unavailable as time of sampling not recorded

Results over 230 *E. coli* MPN/100g arose in January, September and November. These results all occurred after rainfall although the amount that fell prior to sampling on the three occasions varied considerably. The salinities recorded at the time of sampling all approached that of full strength seawater. It was not possible to determine the effect of tide due to the time of sampling not being recorded on two occasions.

11.8 Summary and conclusions

All samples were reported from one location, so it was not possible to undertake any evaluation of geographic patterns in *E. coli* results. Although some analyses were undertaken, low sample numbers (18) dictated against the detection of anything other than gross temporal, seasonal or environmental effects. No statistically significant seasonal or environmental influences were detected. However, all of the results above 230 E. coli MPN/100 g occurred during the autumn or winter and after rainfall.

11.9 Sampling frequency

When a production area has held 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 be decreased from monthly to bimonthly (EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 2007). As Roe Sound is not currently classified, this is not appropriate at present. In addition, it had previously held a seasonal classification.

12. Designated Shellfish Growing Waters Data

The survey area does not coincide with a designated shellfish growing water.

13. Rivers and streams

The following rivers and streams were measured and sampled during the shoreline survey. These represent the most significant freshwater inputs into Roe Sound. The shoreline survey was conducted on the 27th August and 1st September 2009 under dry conditions, although heavy rain fell on the 28th August.

Table 13.1 Stream loadings for Roe Sound

No.	Position	Width (m)	Depth (m)	Flow (m/s)	Discharge (m^3/d)	*E. coli* (cfu/100 ml)	*E. coli* loading (cfu/day)
1	HU 33672 65956	0.2	0.05	0.208	180	380	6.8×10^8
2	HU 32612 66410	2.0	0.16	0.420	11600	2300	2.7×10^{11}

Only two streams of sufficient size for measurement were found during the shoreline survey. The largest loading was for stream 2, which discharges within a bay (Otter Ayre) about 400 m to the south of the mussel lines, and drains an area of acid grassland (i.e. unimproved pasture). The water sample taken from this stream contained 2300 *E. coli* cfu/100ml, a level indicative of a moderate amount of faecal contamination. It is likely to cause at least localised increase in levels of contamination within Otter Ayre. The extent of its impact on the fishery is likely to depend on patterns of water circulation in the area.

Stream 1 carried a much smaller loading and discharges over 1.2 km away from the mussel lines, so is likely to be of negligible impact on the fishery.

Stream loadings are expected to increase significantly following heavy rainfall events, particularly those with high densities of livestock within their catchment areas.

Figure 13.1 Stream loadings

14. Bathymetry and Hydrodynamics

Currents in coastal waters and estuaries are driven by a combination of tide, wind and freshwater inputs. This section aims to make a simple assessment of water movements around the area. Figure 14.1 shows the OS map of Roe Sound and Figure 14.2 shows the bathymetry of the sound. The sound is located between island of Muckle Roe and Mainland. It is approximately 3 km long and, in most part, varies from approximately 200 m to 800 m wide. Although the hydrographic chart shows both a strip of land and an intertidal area between the south-east end of Roe Sound and Busta Voe, there is actually a narrow channel at that point connecting these two water bodies. Local sources indicate that this is only about 1 m in depth (above chart datum) and about 8 m wide. The chart does not show the bathymetry of the sound in much detail. It is up to 30 m deep at the north-western end and is between 10 and 20 m deep at the present mussel fishery. Just to the south west of the fishery there is a shallow embayment (Otter Ayre) with a stream draining to its head.

Figure 14.1 OS map of Roe Sound

Figure 14.2 Bathymetry of Roe Sound

14.1 Tidal Curve and Description

The two tidal curves presented in Figure 14.3 are for Hillswick. This secondary port is located approximately 11 km to the NNW of the Roe Sound fishery. The first tidal curve is for seven days beginning 00.00 BST on 27/08/09 and the second is for seven days beginning 00.00 BST on 03/09/09. This two-week period covers the date of the shoreline survey. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle.

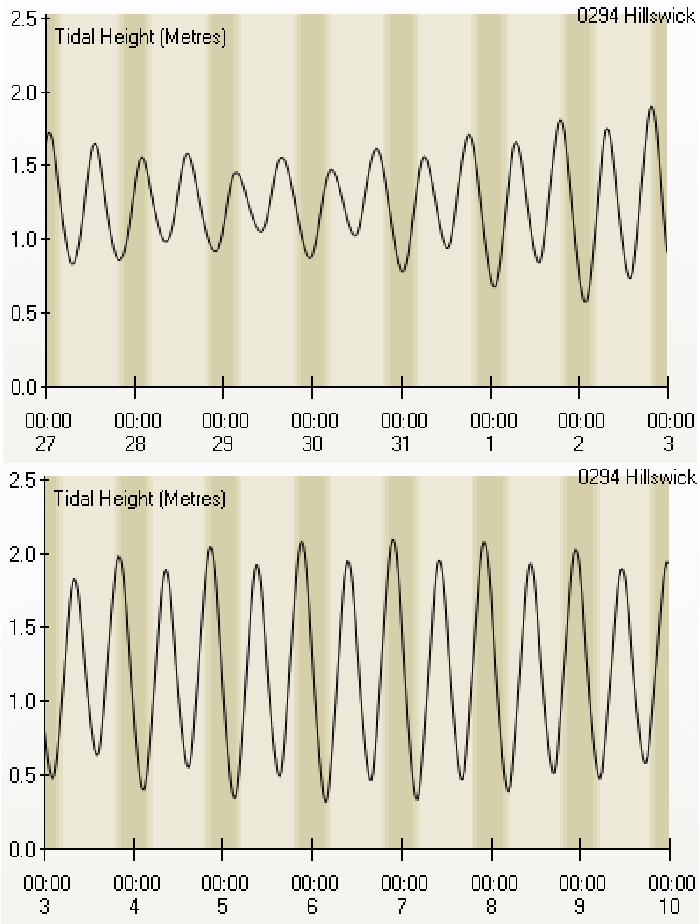

Figure 14.3 Tidal curves at Hillswick

The following is the summary description for Hillswick from TotalTide:

0294 Hillswick is a Secondary Non-Harmonic port.
The tide type is Semi-Diurnal.

HAT	2.4 m
MHWS	2.0 m
MHWN	1.6 m
MLWN	0.8 m
MLWS	0.4 m
LAT	-0.1 m

The tidal range at spring tide is therefore approximately 1.6 m and at neap tide 0.8 m.

14.2 Currents

No tidal stream information was available from TotalTide for the vicinity of Roe Sound. No information could be found in other available published sources (pilots, kayak guides, etc). The tidal range is relatively small and it is expected that the currents in the area will be generally weak except for the narrow and shallow area under the bridge at the south-eastern end of the sound, where currents will be faster but the physical constraints will reduce the volume transferred. Significant mixing will occur at that point. Tidal currents under the bridge are reported by local sources to change directions approximately every 20 minutes. Tides coming in to Busta Voe and Roe Sound will meet in this vicinity, leading to variable flows and timings in the vicinity of the bridge. On spring tides currents at the bridge can be up to 2 m/s (4 knots), and up to 0.5 m/s (1 knot) on neap tides. Eddies are likely to form around Crog Holm, although the exact pattern of these is difficult to predict. They will result in increased mixing of shoreline sources here into the water body as a whole. Between here and the fishery, the channel is straight and fairly uniform, so a bi-directional tidal flow through the section is anticipated, with contamination from shoreline sources tending to hug the shoreline. At the fishery, the sound approximately doubles in width due to a large embayment on the south shore (Otter Ayre) and increases in depth so flows are likely to slow. Flows are likely to be constrained within Otter Ayre, and it is possible that eddies form here. When the tide is running westwards, water will flow in from Busta Voe and through Roe Sound. When it is flowing in the other direction, it is likely that the fishery will more exposed to water flowing in from the open sea in St Magnus Bay, but it is possible that some of this water may have passed through Otter Ayre potentially picking up contamination from the stream discharging to its head, although the majority of contamination from shoreline sources within Otter Ayre remains close to the south shore of the sound where it narrows at the fishery.

From the orientation of the sound and the topography of the area, it would be expected that north and north-westerly winds would have the most effect on surface currents within the sound and would tend to increase the effect of eastbound flows and reduce the effect of westbound flows.

Salinity measurements taken during the shoreline survey showed that at the mussel lines, surface salinity was that of full strength seawater. The average salinity recorded during *E. coli* classification sampling at the site was 33.6 ppt indicating little freshwater influence most of the time, although salinities of 30 ppt were recorded on a few occasions. A salinity measurement taken on the south shore opposite Crog Holm during the shoreline survey (30 ppt) showed that here there was a very localised decrease in salinity resulting from a small freshwater input. A more acute but still very localised decrease in salinity was recorded at Otter Ayre where a larger stream discharges. It is unlikely that there will be significant density driven currents in the sound in the vicinity of the fishery, although small reductions in surface salinity may occur from time to time.

14.3 Conclusions

The tidal range within the sound is relatively small and the associated currents within the main body of the sound are also expected to be weak. The flows at the south-eastern end of the sound are restricted and those under Muckle Roe Bridge are reported to change direction every 20 minutes or so. This will limit the amount of water exchange within Roe Sound from that end. The predominant tidal exchange will therefore occur from the north-western end of the sound. On a flooding tide, water from St Magnus Bay will enter Roe Sound – the fishery will then be impacted by any contamination arising there, or in the north-western end of the sound itself. The freshwater input at the head of Otter Ayre towards the fishery may also impact on the fishery as the tide floods, but this may stay in fairly close proximity to the south shore of the sound and pass to the south of the fishery. Ebbing tides will transport contamination from sources at the south-eastern end of the sound, including any arising from within Busta Voe, towards the fishery. However, the weak tidal currents will mean that the potential distance of transport over one tidal cycle will be limited. Density driven flows are unlikely to be of importance to circulation patterns in Roe Sound. Strong winds from a north westerly direction are likely to increase surface currents associated with eastbound tides, with south easterly winds having the opposite effect.

15. Shoreline Survey Overview

The shoreline survey was conducted on the 27th August and 1st September 2009 under dry conditions, although heavy rain fell on the 28th August.

The fishery consisted of one longline mussel site, where there were three lines with 8 m droppers. A dedicated sampling bag was hung at the south east end of the site at a depth of 6 m.

There were no houses on the north shore, and about 10 homes and farms along the south shore. Only one sewage discharge was found to Roe Sound. This was a small private discharge to the south shore just over 1.3 km from the fishery, a sample of which contained 1.1 x 10^7 *E. coli* cfu/100 ml. Another discharge pipe to Roe Sound was observed about 350 m further west, but this appeared to be carrying either land runoff or agricultural waste at the time, and a water sample from here only contained 390 *E. coli* cfu/100 ml. Other houses here are though to be served by septic tanks discharging to soakaway, one of which was seen during the survey. There is no tourist accommodation around Roe Sound, and only one discharge so it is unlikely that there is a significant increase in sewage contamination during the summer months. There was a small marina with space for about 30 small boats on the north shore just to the west of the bridge, with three additional boats on moorings in the area. A larger fishing boat was seen tied up to a jetty on the south shore by the bridge, and there is also likely to be traffic associated with the fish farms in Roe Sound.

The surrounding land is a mixture of pasture and rough grassland. Sheep were seen mainly along the settled area of the south shore, although a few were seen on the north shore. Large amounts of sheep dung were recorded around the stream that discharges to Otter Ayre, to the southwest of the fishery. Cattle were heard (but not seen) towards the eastern end of the south shore. A small number of seabirds were observed, some of which were resting on the mussel floats, and one seal was seen just off the south shore.

Freshwater samples and discharge measurements were taken at the two main streams draining into the survey area. These streams contained light to moderate levels of contamination (380 and 2300 *E. coli* cfu/100 ml). The larger and more contaminated of the two discharges to Otter Ayre, and the smaller one discharges to the south shore opposite Crog Holm.

Seawater samples taken during the survey contained fairly low levels of *E. coli*. Four samples were taken in the vicinity of the mussel lines, and these contained between 8 and 18 *E. coli* cfu/100 ml. Surface salinity here was 35 ppt. Two samples were taken on the south shore opposite Crog Holm, and these contained 15 and 21 *E. coli* cfu/100 ml. Surface salinity here was 30 ppt indicating some localised freshwater influence. Three samples were taken by Crog Holm and Muckle Roe Bridge, and these contained <1 to 5 *E. coli* cfu/100 ml and surface salinity was not recorded. No seawater samples were taken within Otter Ayre, where the larger and more contaminated stream discharges, although salinity measurements showed a very localised (<10 m) area of reduced salinity where this stream discharges.

Three mussel samples were taken from the fishery. Two were taken at the north western end at depths of 1 and 8 m, which contained 220 and 40 *E. coli* MPN/100 g respectively. One was taken from the dedicated sampling bag at the south eastern which is suspended at a depth of 6 m, and contained <20 *E. coli* MPN/100 g. This limited data suggests a decreasing gradient of contamination from north-east to south-west on the day of sampling and possibly a higher level of contamination at the surface.

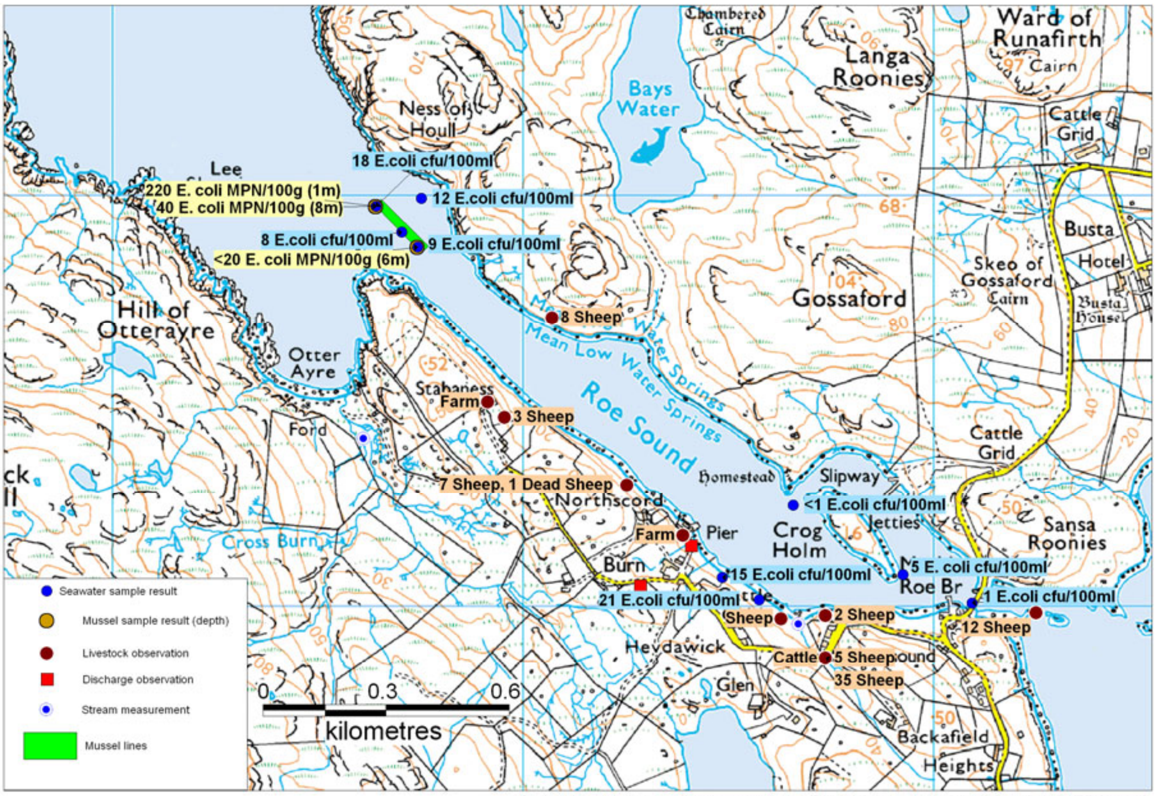

Figure 15.1 Summary of shoreline observations

16. Overall Assessment

Human sewage impacts

There is only one known sewage discharge direct to Roe Sound, which lies just over 1.3 km to the south east of the fishery. It is a small private septic tank discharge, consented for a population of 6 and is therefore unlikely to have a significant impact on the bacteriological quality of the fishery. There are significant sewage inputs to the neighbouring Busta Voe, including a Scottish Water septic tank consented to serve a population of 1000 at its head. Therefore, background levels of contamination within Busta Voe are likely to be slightly elevated. Busta Voe is connected to the south eastern end of Roe Sound via a narrow channel where the incoming tides through both water bodies meet. When the tide flows from Busta Voe into Roe Sound, low levels of contamination originating from sewage sources in Busta Voe may affect the bacteriological water quality at the south-eastern end of Roe Sound. St Magnus Bay has not been covered in the present study or in previous surveys, so it is not known whether there are any significant sources of contamination at this end of Roe Sound.

A small marina is located on the north shore of Roe Sound, just to the west of Muckle Roe Bridge. There is space for about 30 small boats, although the time of shoreline survey none of them appeared to be of sufficient size to have on board toilets. There is a pier on the opposite shore where a larger fishing boat was seen during the shoreline survey, and fish farm service boats also use Roe Sound, so it is possible there are sporadic inputs of sewage contamination from boat traffic.

Seawater samples taken just north of Muckle Roe Bridge during the shoreline survey showed low levels of *E. coli*. This would indicate that, at the time of the survey, neither contamination originating within Busta Voe, or arising from the marina, was significantly affecting water quality in the area.

Agricultural impacts

The surrounding land is a mixture of unimproved and improved grassland. The areas of improved grassland were found towards the south east end of Roe Sound. The shoreline survey confirmed that agriculture in the area is dominated by sheep, with some cattle, although the cattle were heard but not seen. The majority of animals were observed on the south shore of Roe Sound, with highest densities at the eastern end by Muckle Roe Bridge. It is likely that streams draining these areas are subject to contamination by livestock. Direct deposition to the intertidal area may also be of significance where animals are not fenced off from the shore. Large numbers of sheep droppings were found by the stream which discharges into Otter Ayre, but no animals were present at the time. Significant densities of livestock are present around Busta Voe, so contamination from these is likely to be carried into Roe Sound by the tide. It is concluded that livestock are likely to be a significant source of contamination in the area, and this contamination would be carried into Roe Sound mainly by streams draining the areas of pasture on the south shore. Some contamination of livestock origin may also be carried into Roe Sound from Busta Voe.

Wildlife impacts

The main potential wildlife impacts to the fisheries within Roe Sound are seabirds and seals. Large numbers of seabirds breed on Muckle Roe, including all along the shores adjacent to Roe Sound. Seabirds were observed resting on the mussel floats, so there is significant potential for contamination by direct deposition that may result in highly variable levels of contamination within the fishery. Total numbers are likely to be highest during the breeding season, although some species will be resident in the area year round. There are significant seal colonies within St Magnus Bay, and one individual was seen within Roe Sound, so it is likely that they are a regular presence in the area. However, as these animals are highly mobile, the impacts of these on the fishery will be unpredictable, and deposition of faeces by wildlife is likely to be widely distributed around the area.

Seasonal variation

It is unlikely that there are significant increases in the human population on the shores of Roe Sound during the summer holiday season, although it is possible there is an increase in small boat traffic operating from the small marina. It is quite likely that population and boat traffic around Busta Voe increases during the summer, so this may result in a minor increase in levels of contamination in Roe Sound at these times.

Livestock numbers will be higher in the summer, and they are likely to access watercourses to drink more frequently during warmer weather. Therefore, inputs from these will be higher during the summer, particularly following high rainfall events.

The weather is generally wetter and windier in the winter months, so levels of rainfall dependent faecal contamination entering the production area from these sources is likely to be higher on average during the autumn and winter months. High rainfall events can occur at any time of year, and these may result in a ‘first flush’ of highly contaminated runoff from pastures. This effect may be particularly acute during the summer, when livestock numbers are likely to be highest, and any preceding dry periods result in a build-up of faecal contamination on pastures.

An analysis of historic *E. coli* monitoring data identified no statistically significant seasonal pattern in levels of contamination at the fishery, and no relationship between water temperature and *E. coli* results. Sample numbers were low, however all of the results above 230 *E. coli* MPN/100 g occurred during autumn or winter. When the site was previously classified (2006 and 2007/8) it received seasonal classifications, with class B months mostly during the winter, which is an unusual seasonal pattern in Shetland mussel fisheries.

In conclusion, the main source of microbial contamination into Roe Sound is from livestock origin and it will be elevated during the summer months, as livestock numbers are higher at these times and they are more likely to access streams to drink. There may also be increased contamination from human and livestock sources within Busta Voe in the summer. Conversely, the limited historic *E. coli* monitoring results and the historic classifications derived from them indicate higher levels of contamination during the winter months.

Rivers and streams

Only two streams of sufficient size to allow sampling and measurement were found during the shoreline survey. These both drained areas of pasture. Water samples from these stream inputs showed moderate concentrations of *E. coli* (380 and 2300 *E. coli* cfu/100ml) suggesting they carry contamination from livestock. The smaller, and less contaminated of these streams discharges over 1.2 km away from the mussel lines, and carried a very small *E. coli* loading so is likely to be of negligible impact on the fishery. The larger stream discharges in Otter Ayre, 400 m to the south of the mussel lines. It is likely to cause a localised increase in levels of contamination within Otter Ayre, but the extent of its impact on the fishery is likely to depend on patterns of water circulation in the area. It is probable that the loadings contributed by these streams will increase significantly following periods of heavy rainfall, as livestock are present in their catchment areas.

Meteorology, hydrology, and movement of contaminants

Tidal currents within the main body of Roe Sound are expected to be weak. The flows at the south-eastern end of the sound are restricted, limiting the amount of water exchange within Roe Sound from Busta Voe. The predominant tidal exchange will therefore occur from the north-western end of the sound. On a flooding tide, the fishery will be impacted by any contamination arising in the north-western end of the sound itself or, more broadly, in St. Magnus Bay. The freshwater input at the head of Otter Ayre towards the fishery may also impact on the fishery as the tide floods, but this may stay in fairly close proximity to the south shore of the sound and pass to the south of the fishery. Ebbing tides will transport contamination from sources at the south-eastern end of the sound towards the fishery. However, the weak tidal currents will mean that the potential distance of transport over one tidal cycle will be limited. Strong winds from a north westerly direction are likely to increase surface currents associated with eastbound tides, with south easterly winds having the opposite effect.

Temporal and geographical patterns of sampling results

Historical *E. coli* monitoring results were only reported from one location, so a geographic evaluation of these was not possible. No overall temporal trends were identified within this limited dataset.

Shoreline survey sampling results were the only available information on spatial patterns of levels of contamination in Roe Sound. The highest seawater sample results were obtained at the shoreline on the south side of the south-eastern end of the sound. This was within the general area of the sewage discharge and two streams, and in the region of the fishery. It should be noted that no sample was taken within Otter Ayre, where it is probable that a stream cause deterioration in seawater quality. Three mussel samples were taken from the fishery. Two were taken at the north-western end at depths of 1 and 8 m, which contained 220 and 40 *E. coli* MPN/100g respectively. One was taken from the dedicated sampling bag that is suspended at a depth of 6 m at the south-eastern end of the site, and contained <20 *E. coli* MPN/100g. This very limited data suggests that there may be a gradient of contamination across the site and that levels of contamination may be higher towards the surface. The former is consistent with the results of the seawater samples taken at the fishery at the time of the shoreline survey.

Overall conclusions

Overall, contamination of the fishery may arise from three broad areas: within the sound itself; from St Magnus Bay; from Busta Voe. Available information indicates that contamination from local sources within Roe Sound will predominantly affect the microbiological quality of the shellfishery.

The one small sewage discharge is located some distance from the fishery and is unlikely to significantly impact the water quality there. The streams at the south-eastern end of the sound, and any contamination arising from within Busta Voe, may also contribute to background levels of *E. coli* in the sound. However this is not expected to have an impact on the spatial extent of contamination across the fishery. The predominant influence on this is likely to be the stream at the head of Otter Ayre and thus any contamination is expected to be highest at the north-western end of the mussel farm. Contributions from seabirds are likely to equally affect any part of the fishery, although the effect would be greatest at the surface.

There is likely to be an element of seasonality to some sources of contamination, namely livestock and seabirds both of which will be present in higher numbers during the summer. However, the limited historic *E. coli* monitoring results suggest higher levels of contamination arose during the winter months.

17. Recommendations

Production area

It is recommended that the production area be defined as:

Bounded by lines drawn between HU 3264 6711 and HU 3254 6702 and between HU 3254 6702 and HU 3280 6678 and between HU 3280 6678 and HU 3289 6686 extending to MHWS.

This will enclose the present position of the fishery while excluding areas of potentially higher contamination towards Otter Ayre and the sources at the south-eastern end of the sound.

Representative Monitoring Point

It is recommended that the RMP be located at HU 3265 6698. This is at the north-western end of the lines where levels of contamination are potentially higher. The recommended depth for sampling is 1 m given that there is some indication that the level of contamination may be highest near the surface.

Tolerance

The recommended tolerance is 20 m. Given that this is an aquaculture site, it should be possible to access stock within this tolerance. It does allow for some variation in accessing animals of sufficient size and drift of the lines themselves. If either of these factors presents a problem with regard to sampling within the recommended tolerance, consideration should be given to placing a bag of shellfish at the recommend location and depth specifically for sampling purposes. If this is done, shellfish should be placed in situ for at least two weeks prior to sampling to ensure that they have taken on the microbiological quality of the RMP.

Frequency

Historic *E. coli* monitoring results suggest seasonal variations occur in contamination levels at the fishery, therefore monthly monitoring is recommended.

Figure 17.1 Recommendations for Roe Sound

18. References

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Sampling Plan for Roe Sound

PRODUCTION AREA	SITE NAME	SIN	SPECIES	TYPE OF FISHERY	NGR OF RMP	EAST	NORTH	TOLERANCE (M)	DEPTH (M)	METHOD OF SAMPLING	FREQ OF SAMPLING	LOCAL AUTHORITY	AUTHORISED SAMPLER(S)	LOCAL AUTHORITY LIAISON OFFICER
Roe Sound	Ness of Hull	SI 334 715	Common mussels	Longline	HU 3265 6698	432650	1166980	20	1	Hand	Monthly	Shetland Islands Council	Sean Williamson George Williamson Kathryn Winter Marion Slater	Sean Williamson

Table of Proposed Boundaries and RMPs for Roe Sound

Production Area	Species	SIN	Existing Boundary	Existing RMP	New Boundary	New RMP	Comments
Roe Sound	Common mussels	SI 334	Formerly the area bounded by lines drawn between HU 3420 6590 and HU 3420 6605 and between HU 3165 6750 and HU 3250 6750 (currently declassified)	Formerly HU 328 670 (currently declassified)	Area bounded by lines drawn between HU 3264 6711 and HU 3254 6702 and between HU 3254 6702 and HU 3280 6678 and between HU 3280 6678 and HU 3289 6686 extending to MHWS	HU 3265 6698	Boundary moved to exclude south shore. RMP relocated to northwest extremity of current farm.

Geology and Soils Information

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

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

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

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

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

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

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

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

These component soils were classed broadly into two groups based on whether they are freely or poorly draining. Drainage classes were created based on information obtained from the both the Macaulay Institute website and personal communication with Dr. Alan Lilly. GIS map layers were created for each class with poorly draining classes shaded red, pink or orange and freely draining classes coloured blue or grey. These maps were then used to assess the spatial variation in soil permeability across a survey area and it's potential impact on runoff.

Glossary of Soil Terminology

Calcareous: Containing free calcium carbonate.

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

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

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

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

References

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General Information on Wildlife Impacts

Pinnipeds

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

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

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

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

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

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

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

Cetaceans

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

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

During 2001-2002, there were confirmed sightings of the following species (Shetland Sea Mammal Group 2003):

Table 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*.

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

Birds

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

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

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

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

Deer

There are no deer on Shetland.

Otters

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

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

References:

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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 *E. coli* data was log transformed prior to statistical tests.

Section 11.5 One way ANOVA comparison of *E. coli* results by season

```
Source  DF     SS     MS     F      P
Season   3  1.908  0.636  1.25  0.329
Error   14  7.125  0.509
Total   17  9.033

S = 0.7134   R-Sq = 21.12%   R-Sq(adj) = 4.22%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level  N    Mean   StDev  ---------+---------+---------+---------+
1      4  1.4109  0.4437  (------------*-----------)
2      6  1.3775  0.5390    (---------*---------)
3      5  1.9877  0.8807           (----------*-----------)
4      3  2.1255  0.9948          (-------------*--------------)
                          ---------+---------+---------+---------+
                                1.20      1.80      2.40      3.00

Pooled StDev = 0.7134
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 2 day rainfall

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = -0.165
P-Value = 0.556
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 7 day rainfall

```
Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.258
P-Value = 0.354
```

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the spring/neap cycle

CIRCULAR-LINEAR CORRELATION
Analysis begun: 19 November 2009 10:18:16

Variables (& observations)	r	p
Angles & Linear (18)	0.298	0.262

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the high/low cycle

CIRCULAR-LINEAR CORRELATION
Analysis begun: 19 November 2009 10:17:18

Variables (& observations)	r	p
Angles & Linear (14)	0.331	0.297

Section 11.6.5 Regression analysis – *E. coli* result vs salinity

```
The regression equation is
```

```
log e coli for salinity = 2.07 - 0.010 salinity


Predictor     Coef  SE Coef      T      P
Constant     2.070    3.480   0.59  0.562
salinity   -0.0105   0.1032  -0.10  0.921


S = 0.808989   R-Sq = 0.1%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF      SS      MS     F      P
Regression       1  0.0067  0.0067  0.01  0.921
Residual Error  13  8.5080  0.6545
Total           14  8.5147
```

Hydrographic Methods

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

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

<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.

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

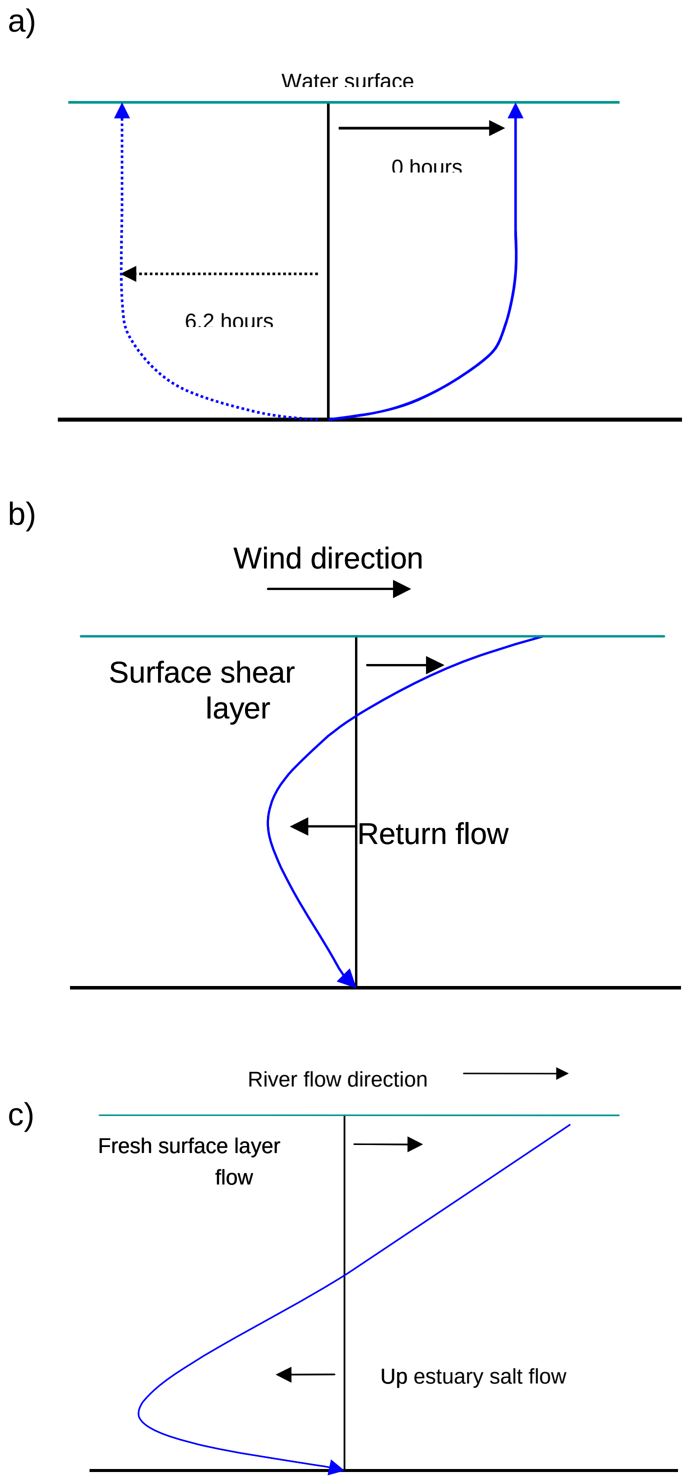

Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

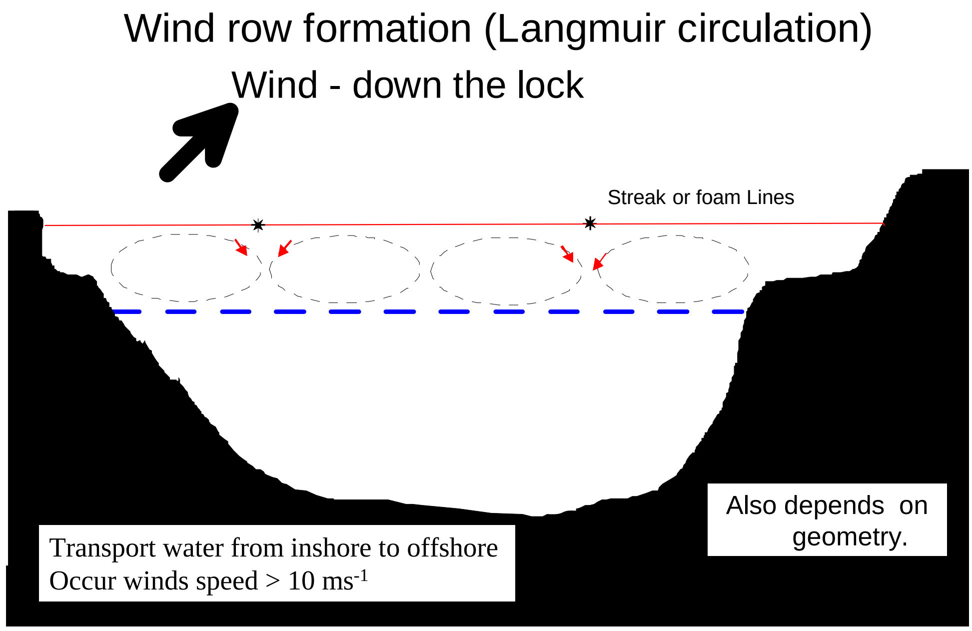

Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

<u>Non-modelling Assessment</u>

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

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

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

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

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

References

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

Glossary

The following technical terms may appear in the hydrographic assessment.

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

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

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

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

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

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

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

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

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

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

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

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

Shoreline Survey Report

Roe Sound (SI 334)

Scottish Sanitary Survey Project Cefas

Shoreline Survey Report

Areas surveyed:

Production Area	Site	SIN	Species	Harvester
Roe Sound	Ness of Hull	SI 334 715 08	Common mussel	Addie Doull

Local Authority: Shetland Islands Council
Status: New
Date Surveyed: 27 August and 1 September 2009
Surveyed by: M. Price-Hayward, S. Williamson
RMPs: None yet assigned

Weather observations
Overcast to partly cloudy, Winds S F3-4, T to 16C. Rain and gales on 28 August.

Site Observations

Fishery
The fishery at Roe Sound is located approximately 1.6 km west of the Muckle Roe Bridge. It consists of a longline mussel farm containing three lines with 8m droppers. A dedicated sampling bag was hung at HU 32745 66875 at a depth of 6m.

Sewage/Faecal Sources
Roe Sound is populated only on the southern shore, where a number of homes and farms were observed, with 10 noted from the shoreline. There were no community septic tanks and the homes here will have private septic tanks discharging either to soakaway or to the sound. One active septic discharge (1x107 *E. coli*/100ml) was observed on the south shore over 1km east of the mussel farm. The flow was very low at the time (flow 3ml/sec). One other discharge pipe was observed and this appeared to carry fermented waste of some type and contained 390 *E. coli*/100ml. No flow measurement was possible due to the position of the pipe.

Sheep were observed mostly along the southern shore, where farms were located. Cattle were heard, but not directly observed. Large numbers of sheep droppings were observed around the stream that discharges into Otter Ayre, southwest of the shellfish farm. Two streams were observed and measured. A sample taken from the stream at Otter Ayre contained 2300 *E. coli*/100ml, while a sample taken from the stream west of the bridge (Table 1, No. 28) contained 380 *E. coli*/100ml.

Seasonal Population
There was no tourist accomodation in the sound, however there is a hotel to the east on the shore of Busta Voe.

Boats/Shipping
A small marina is located on the north shore just west of the bridge. At the time of survey, this contained space for approximately 30 small angling boats and had no other facilities other than a slipway. Three additional boats were

observed on moorings in the area. On the south shore, just below the bridge, was a jetty and fishing boat.

There are fish farm cages in the Roe Sound, and a large workboat was observed heading toward the sound from Busta Voe to the east.

Land Use
Land use along the sound is primarily crofting and livestock grazing, either on pasture or rough grassland. Barns and silage bales were observed on the south side of the voe, indicating a year round livestock presence there.

Wildlife/Birds

A small number of gulls and other seabirds were observed during the survey. A few birds were observed resting on the mussel floats. One seal was seen in the water near the south shore, closer to the cage fish farms. While no otters were observed, it is likely that they are present in the stream that flows into Otter Ayre.

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.

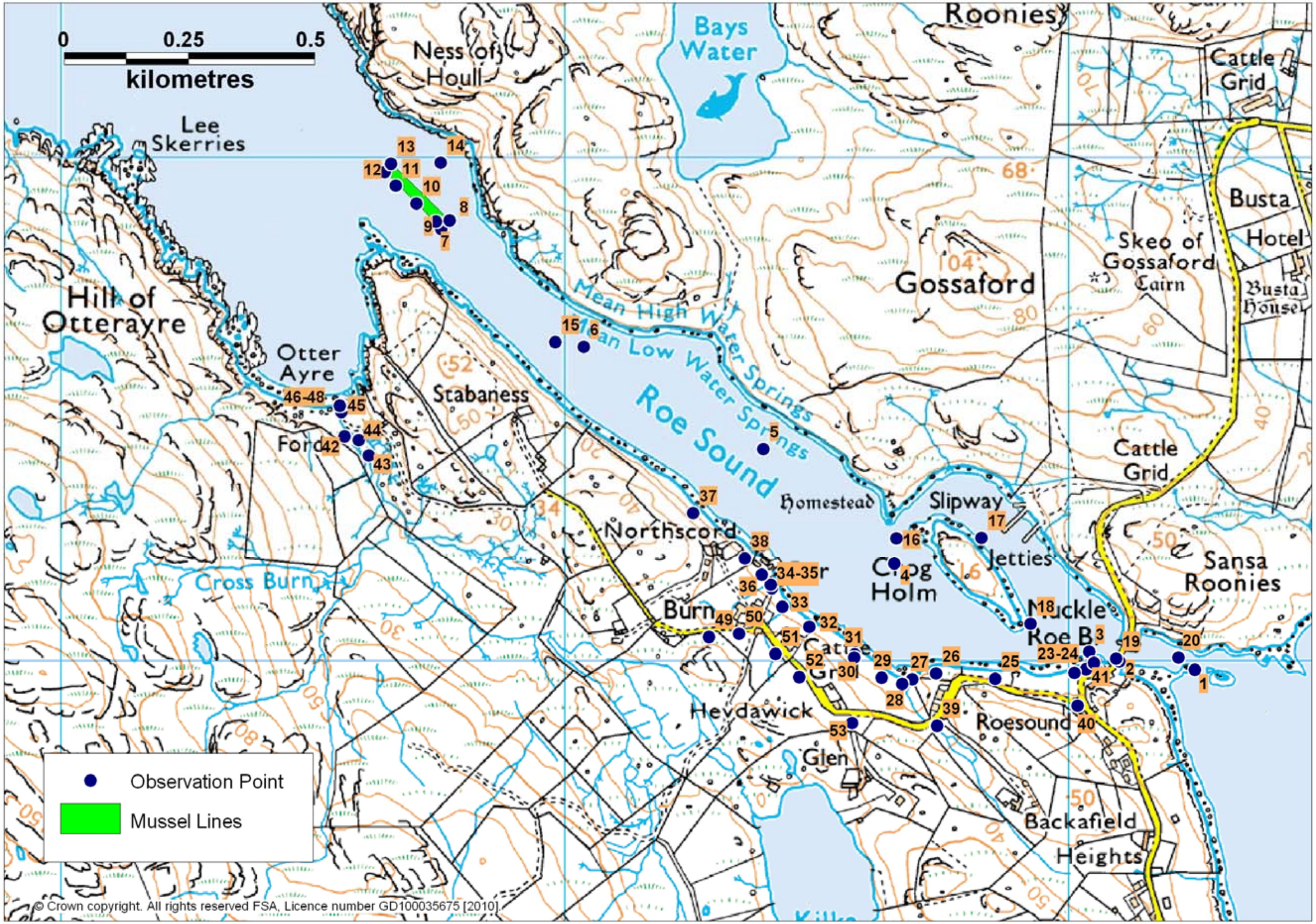

Figure 1 Map of Shoreline Observations

Table 1 Shoreline Observations

Obs No.	Date	Time	Grid Ref	Easting	Northing	Way point	Associated Photograph	Note
1	27/08/2009	09:29:07	HU 34253 65984	434253	1165984	62		12 sheep, steep shoreline
2	27/08/2009	09:29:58	HU 34103 66001	434103	1166001	63		Bridge
3	27/08/2009	09:30:15	HU 34043 66020	434043	1166020	64		Fishing boat and shed
4	27/08/2009	09:31:14	HU 33656 66195	433656	1166195	65		3 fish farm cages, homes on south shore
5	27/08/2009	09:31:55	HU 33396 66423	433396	1166423	66		4 fish farm cages to the south, sheep tracks visible on hill
6	27/08/2009	09:32:43	HU 33039 66626	433039	1166626	67		8 sheep
7	27/08/2009	09:33:38	HU 32756 66860	432756	1166860	68	Figure 4	Corner of lines, 3 long lines, 8m droppers. Stock too small to sample here
8	27/08/2009	09:35:38	HU 32772 66877	432772	1166877	69		Corner of lines
9	27/08/2009	09:38:21	HU 32745 66875	432745	1166875	70		Mussel sample 1. Water sample 1. RMP bag at 6m depth, surface salinity 35ppt, fulmars visible on cliffside to the south
10	27/08/2009	09:46:28	HU 32706 66911	432706	1166911	71		Water sample 2, mid farm
11	27/08/2009	09:48:45	HU 32665 66947	432665	1166947	72	Figure 5	5 cormorants and 1 gull resting on floats
12	27/08/2009	09:49:05	HU 32643 66974	432643	1166974	73		Corner of lines, water sample 3, shellfish sample 2 (top) and 3 (bottom)
13	27/08/2009	10:00:04	HU 32656 66991	432656	1166991	74		Corner of lines
14	27/08/2009	10:01:00	HU 32754 66993	432754	1166993	75		Water sample 4, surface salinity 35ppt
15	27/08/2009	10:04:52	HU 32982 66636	432982	1166636	76		3 sheep on clifftop to south, 1 farm with barns and silage also
16	27/08/2009	10:08:10	HU 33660 66246	433660	1166246	77		Water sample 5 taken at west entrance to marina
17	27/08/2009	10:09:58	HU 33829 66247	433829	1166247	78	Figure 6	Marina with space for up to 30 small angling boats, no other facilities. Additional 3 boats on moorings
18	27/08/2009	10:11:06	HU 33927 66076	433927	1166076	79		Water sample 6, 2 gulls
19	27/08/2009	10:12:53	HU 34096 66006	434096	1166006	80		Water sample 7
20	27/08/2009	10:13:55	HU 34220 66008	434220	1166008	81		Rocky shore with cliffs
21	27/08/2009	10:16:58	HU 35316 66165	435316	1166165	82		Large workboat heading out
22	27/08/2009	10:19:04	HU 35968 66443	435968	1166443	83		Blueshell mussels shorebase
23	27/08/2009	11:51:35	HU 34037 65985	434037	1165985	84	Figure 7	Jetty with 1 fishing boat
24	27/08/2009	11:53:07	HU 34014 65978	434014	1165978	85	Figure 8	Drainage pipe. Water sample 8
25	27/08/2009	12:02:39	HU 33856 65966	433856	1165966	86		Dry field drain
26	27/08/2009	12:12:16	HU 33739 65977	433739	1165977	87	Figure 9	Drainage pipe, dripping 30ml-10s, foul odour. 1 house, 2 sheep up shore. Water sample 9
27	27/08/2009	12:20:03	HU 33692 65965	433692	1165965	88		2 oystercatchers

Obs No.	Date	Time	Grid Ref	Easting	Northing	Way point	Associated Photograph	Note
28	27/08/2009	12:21:35	HU 33672 65956	433672	1165956	89		Many clam shells on shore, small stream too shallow for flow meter, so scoured out to measure. 20cm wide, 5 cm deep, flow 0.208m/s, Water sample 10
29	27/08/2009	12:32:42	HU 33631 65969	433631	1165969	90		Sheep grazing up hillside
30	27/08/2009	12:35:56	HU 33576 66008	433576	1166008	91		Thick green growth on shore. No pipes visible. House up hill.
31	27/08/2009	12:37:35	HU 33577 66015	433577	1166015	92		Seawater sample taken, salinity 30ppt. Water sample 11
32	27/08/2009	12:43:36	HU 33487 66069	433487	1166069	93	Figure 10	More green algae in water, house up hill from shore. Water sample 12
33	27/08/2009	12:51:00	HU 33433 66109	433433	1166109	94		Area of green algae below a house, can hear water trickling under grass
34	27/08/2009	12:55:50	HU 33412 66146	433412	1166146	95	Figure 11	Black PVC drainage pipe, running, foam and smell of silage or brewery waste. Water sample 13
35	27/08/2009	12:59:53	HU 33410 66153	433410	1166153	96		Shore base for salmon farm, disused
36	27/08/2009	13:02:11	HU 33392 66173	433392	1166173	97		Farm with occupied home
37	27/08/2009	13:09:13	HU 33256 66296	433256	1166296	98		1 dead sheep, 7 live sheep, large numbers of large cockle shells
38	27/08/2009	13:19:48	HU 33359 66206	433359	1166206	99		Seal observed in water
39	27/08/2009	13:36:29	HU 33739 65873	433739	1165873	100	Figure 12	Farm up track at this point, 5 sheep seen from shore, 35 seen later from the road. Cattle heard but not seen. Photo, view NW along shore.
40	27/08/2009	13:46:39	HU 34020 65913	434020	1165913	101		3 houses and 2 sheds
41	27/08/2009	13:48:29	HU 34052 65998	434052	1165998	102		Tidal rapids at bridge, main flow is westward, wind driving counter current eastward along shore. Wind SW F4. Fisherman reported that tide often runs counterflow under the pier. At 1405, tide was visibly slower.
42	01/09/2009	14:38:13	HU 32564 66448	432564	1166448	227		25 sheep, stream
43	01/09/2009	14:39:53	HU 32612 66410	432612	1166410	228	Figure 13	Burn, w 2m, d 16cm, flow ave 0.42. Water sample 14
44	01/09/2009	14:46:29	HU 32592 66441	432592	1166441	229		Large numbers of sheep droppings
45	01/09/2009	14:49:19	HU 32557 66496	432557	1166496	230	Figure 14	Bank erosion showing level of recent flow
46	01/09/2009	14:52:35	HU 32560 66512	432560	1166512	231		Salinity 36ppt
47	01/09/2009	14:54:24	HU 32556 66510	432556	1166510	232		Salinity 10 ppt 0.5 meter away and 20 ppt 1m away from outfall of stream, 0 ppt in stream
48	01/09/2009	14:55:31	HU 32554 66509	432554	1166509	233		Flow of fresh water appears to form narrow channel of reduced salinity, with drop of 5ppt for each 1-1.5 foot away from stream.
49	01/09/2009	15:17:20	HU 33288 66049	433288	1166049	234		Septic tank behind trailer home. 15 sheep
50	01/09/2009	15:18:22	HU 33347 66056	433347	1166056	235		Farm

Obs No.	Date	Time	Grid Ref	Easting	Northing	Way point	Associated Photograph	Note
51	01/09/2009	15:18:52	HU 33420 66016	433420	1166016	236		House
52	01/09/2009	15:19:11	HU 33467 65970	433467	1165970	237		2 houses, 15 sheep
53	01/09/2009	15:19:58	HU 33572 65878	433572	1165878	238		Farm located up track away from road
54	01/09/2009	15:20:37	HU 33741 65873	433741	1165873	239		Farm located up track, house and 10 sheep

Photos referenced in the table can be found attached as Figures 4-14.

Sampling
Water and shellfish samples were collected at sites marked on the map. Samples were Bacteriology results follow in Tables 2 and 3. All samples were submitted to SSQC for *E. coli* analysis.

Salinity readings were taken using a refractometer.

Table 2 Water Sample Results

No.	Date	Sample	Grid Ref	Type	*E. coli* (cfu/100ml)	Salinity (ppt)
1	27/08/2009	RS1	HU 32745 66875	Seawater	9	35
2	27/08/2009	RS2	HU 32706 66911	Seawater	8	
3	27/08/2009	RS3	HU 32643 66974	Seawater	18	
4	27/08/2009	RS4	HU 32754 66993	Seawater	12	35
5	27/08/2009	RS5	HU 33660 66246	Seawater	<1	
6	27/08/2009	RS6	HU 33927 66076	Seawater	5	
7	27/08/2009	RS7	HU 34096 66006	Seawater	1	
8	27/08/2009	RS8	HU 34014 65978	Freshwater	60	
9	27/08/2009	RS9	HU 33739 65977	Freshwater	11000000	
10	27/08/2009	RS10	HU 33672 65956	Freshwater	380	
11	27/08/2009	RS11	HU 33577 66015	Seawater	21	30
12	27/08/2009	RS12	HU 33487 66069	Seawater	15	
13	27/08/2009	RS13	HU 33412 66146	Freshwater	390	
14	01/09/2009	RS14	HU 32612 66410	Freshwater	2300	

Table 3 Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	Depth (m)	*E. coli* (MPN/ 100g)
1	27/08/2009	RS Mussel 1	HU 32745 66875	Mussel	6	<20
2	27/08/2009	RS Mussel 2	HU 32643 66974	Mussel	1	220
3	27/08/2009	RS Mussel 3	HU 32643 66974	Mussel	8	40

Figure 2 Water sample results Roe Sound

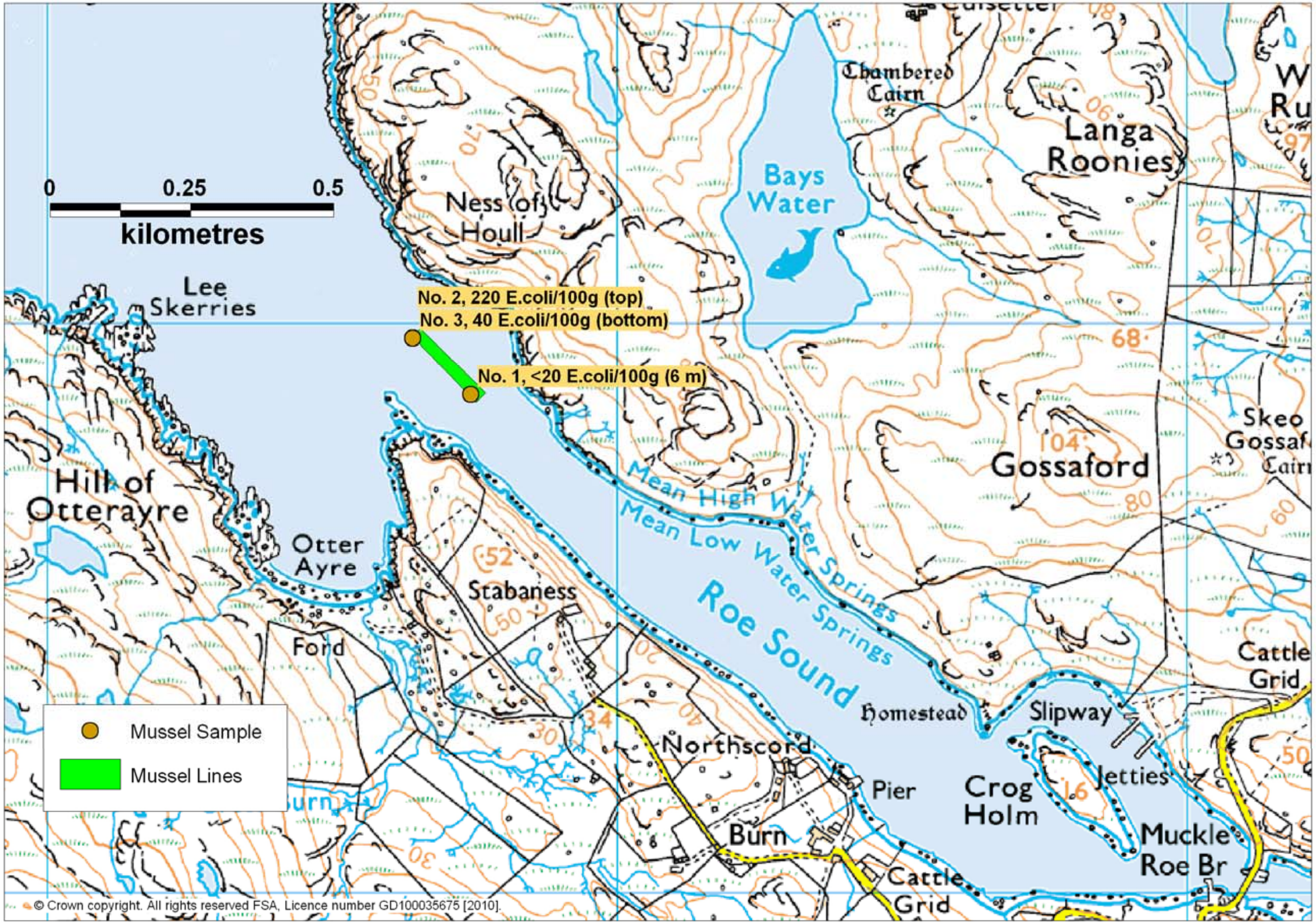

Figure 3 Shellfish sample results Roe Sound

Photographs

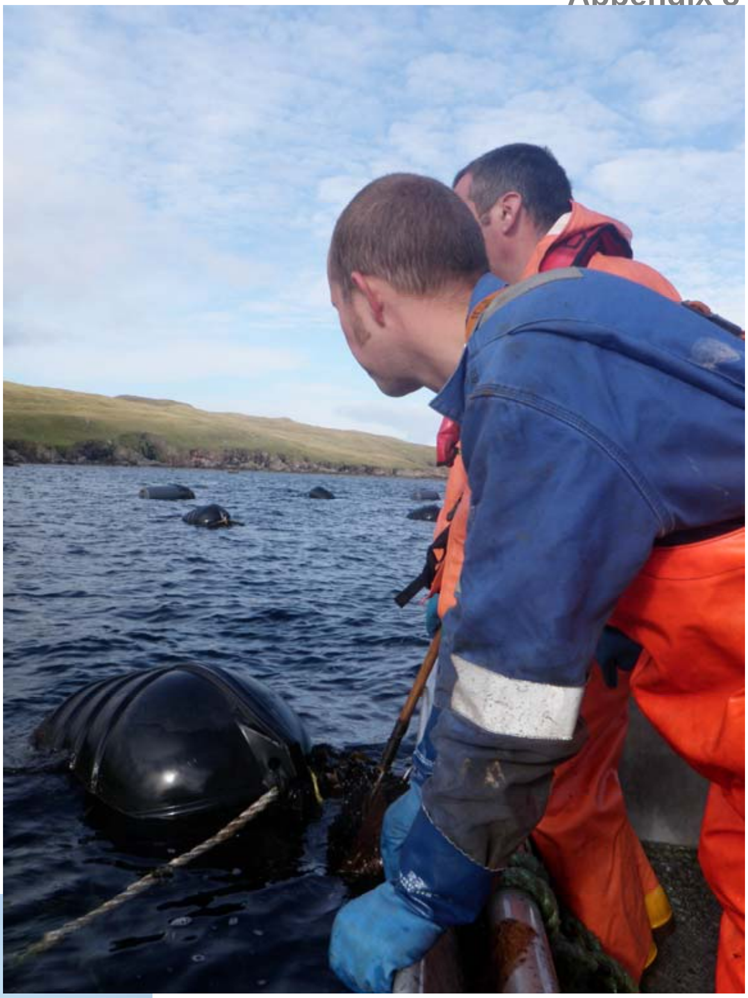

Figure 4. Assessing lines at Roe Sound

Figure 5. Seabirds resting on floats

Figure 6. Marina at east end of Roe Sound

Figure 7. Jetty and fishing boat

Figure 8. Drainage pipe

Figure 9. Foul discharge pipe below house

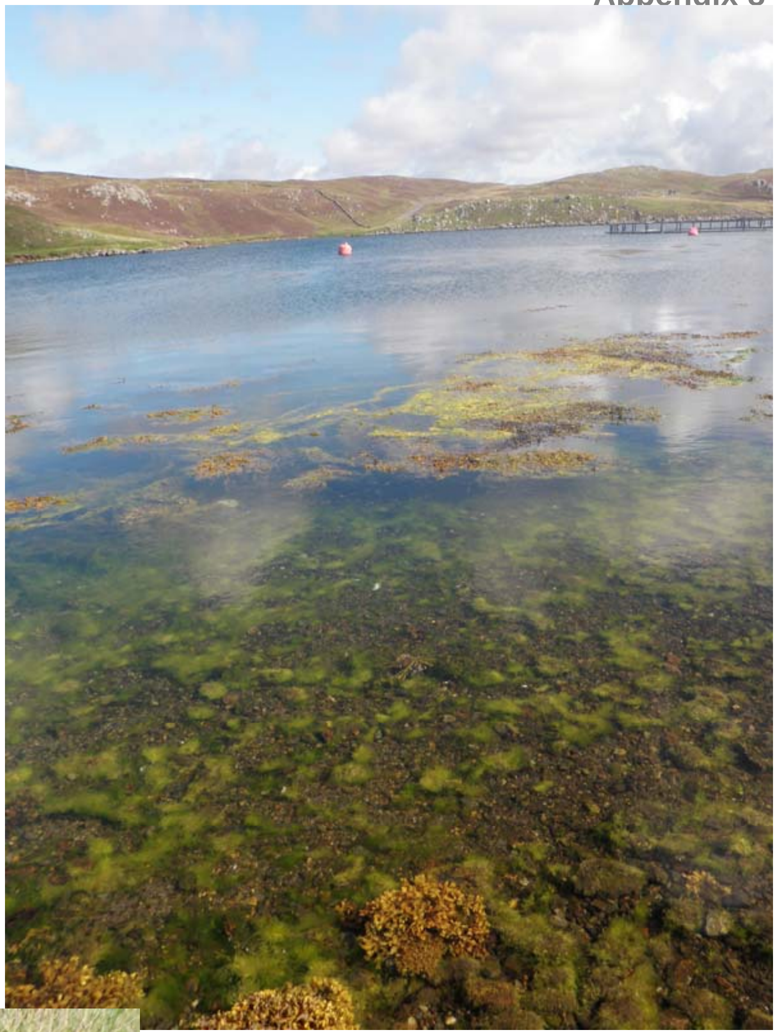

Figure 10. Algal growth in water, south shore

Figure 11. Discharge pipe with foam

Figure 12. View along shoreline looking northwest from point 39.

Figure 13. Burn at Otter Ayre

Figure 14. Bank erosion showing recent higher flow of burn (red arrows)