Scottish Sanitary Survey Project

Sanitary Survey Report

Sound of Mull: Aros

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Cefas

FOOD STANDARDS AGENCY SCOTLAND

Buidheann Inbhe-Bìdhe an Alba

Report Distribution – Sound of Mull: Aros

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

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

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1. General Description

The Sound of Mull: Aros area is located in Salen Bay, on the eastern side of the Isle of Mull, off the west coast of Scotland. Salen Bay is 2.2 km in length and 0.8km wide and opens to the Sound of Mull to the northeast. The depth of the bay varies from 0 to 20m and the bay is relatively sheltered from most directlons. A sanitary survey was undertaken in response to the submission of an application to harvest Pacific oysters within the established production area for common mussels in Salen Bay.

Figure 1.1 Location of Sound of Mull: Aros

2. Fishery

The fishery at Sound of Mull: Aros was composed of one area of trestles of Pacific Oysters (*Crassostrea gigas*) at the time of shoreline survey. The area is also classified for the harvest of shore mussels, although these are not commercially exploited.

Table 2.1. Sound of Mull: Aros fishery

Production Area	Site	SIN	Species
Sound of Mull: Aros	Aros	AB 257 820 13	Pacific oysters
Sound of Mull: Aros	Aros	AB 257 075 08	Common mussels

The current production area boundaries for Sound of Mull: Aros are given as the area bounded by an inshore of a line drawn between NM 5651 4546 and NM 5769 4392. There is currently a nominal RMP for shore mussels located at NM 564 445.

At the time of survey, the harvester had 20 trestles down at the site with plans to add approximately 10 more. The trestles are accessible only during low water at spring tides and are located at the mouth of the Aros River, where the harvester found the lower salinity water kept growth of tube worms on the oyster shells to a minimum. There are no depuration facilities in the area.

Stock may be harvested at any time of year, depending upon market conditions, so year-round classification is sought.

The area was classified for the harvest of shore mussels on request of the harvester to ascertain whether levels of contamination in the area were suitable for the development of the oyster fishery. It is not believed that these are harvested commercially, although it is possible that people collect them for personal consumption from time to time. Shore mussels are the property of the Crown Estate in Scotland, and it is an offence to collect them without permission. As there is no active commercial mussel fishery here, it will not be considered further in this report.

A detailed map showing the extent of the production area classified for the harvest of mussels, the mussel RMP and the extent off the oyster trestles are shown in Figure 2.1.

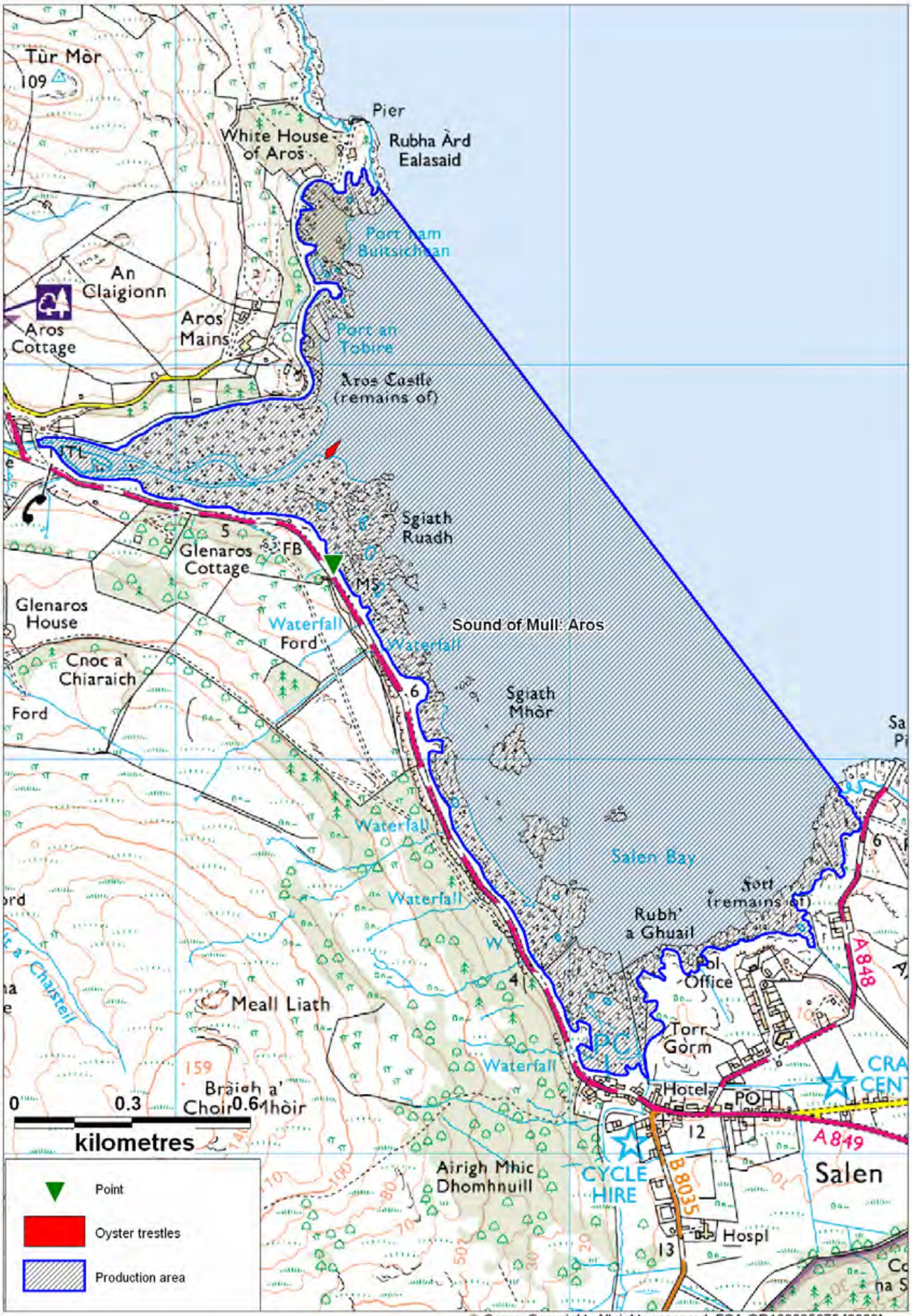

Figure 2.1 Sound of Mull: Aros fishery

3. Human Population

The figure below shows information obtained from the General Register Office for Scotland on the population recorded in the vicinity of Salen Bay.

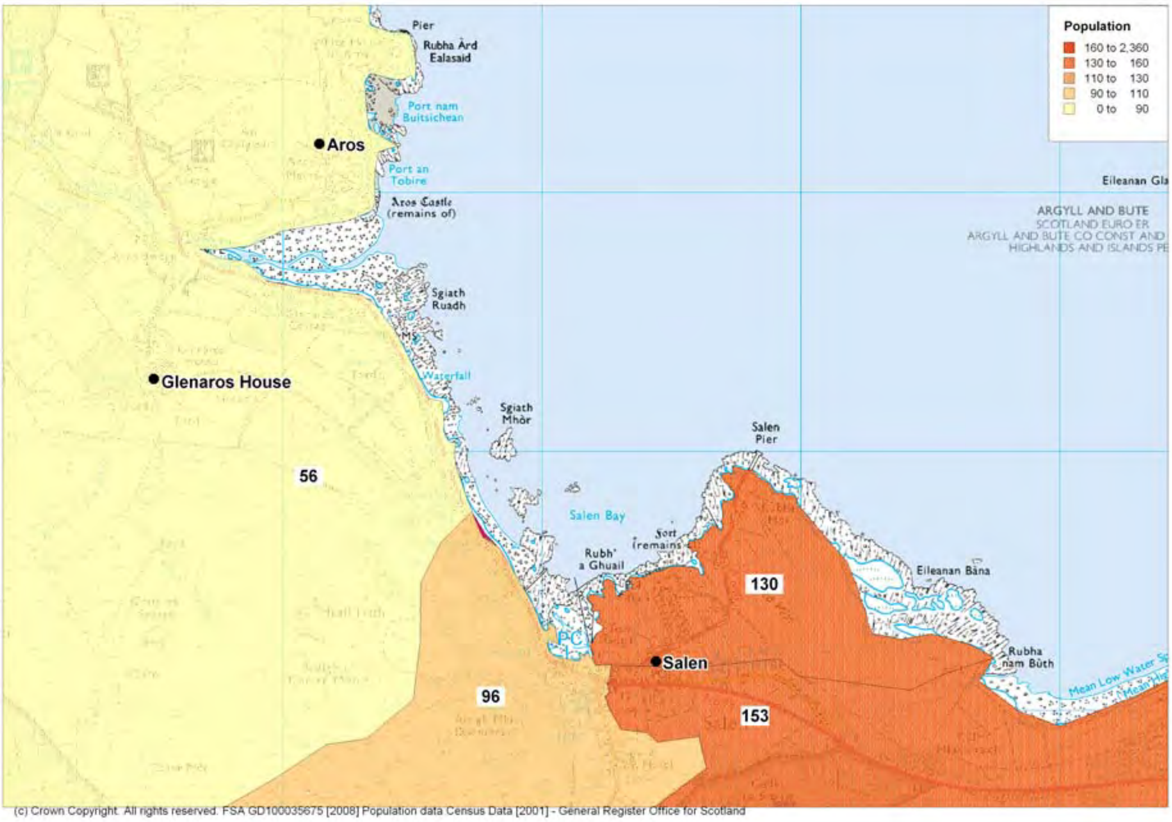

Figure 3.1 Human population surrounding Sound of Mull: Aros

The population for the four census output areas bordering immediately on the Sound of Mull: Aros area are:

60QD000120	130
60QD000173	153
60QD000714	96
60QD000121	56
Total	435

There are two main settlements within this area: Salen and Aros. The majority of the population is concentrated in the southwest corner of the bay around Salen and any faecal pollution from human sources is likely to be concentrated in this area.

The area is popular with tourists so the population will increase during the summer tourist season.

4. Sewage Discharges

Two community septic tanks was identified by Scottish Water for the area, both of which serve the settlement of Salen. A separate combined sewer overflow (CSO) and emergency overflow (EO) was identified at Salen. Details are presented in Table 4.1, and a map indicating their catchments is presented in Figure 4.1.

Table 4.1 Discharges identified by Scottish Water

NGR	Discharge Name	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Consent/ design pop	Q&S III Planned improve-ment?	Ref
NM 5762 4380	Ardmore Road Septic Tank	Continuous	Septic tank	3	20	No	
NM 5728 4416	Salen Septic Tank	Continuous	Septic Tank	47	-	-	WPC-C-W12124 (oufall)
NM 5713 4351	Salen CSO/EO	Intermittent	6 mm screen	Overflow operates at 6.27 l/s	-	-	WPC-C-W12124 (oufall)

No sanitary or microbiological data is available for these discharges, and the predicted spill frequency of the Salen CSO/EO is not known.

A number of discharge consents have been issued within the local area by the Scottish Environment Protection Agency (SEPA). Details of these are presented in Table 4.2. No permit was provided for the discharge associated with the discharge from the Ardmore Road Septic Tank.

Table 4.2 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/1020597	NM 5637 4564	Domestic	Septic tank	-	5	Partial soakaway
CAR/R/1014308	NM 5548 4529	Domestic	Septic tank	-	15	Land
CAR/R/1016600	NM 5605 4500	Domestic	Septic tank	-	8	Land
CAR/R/1021680	NM 5625 4501	Domestic	Septic tank	-	10	Land
CAR/R/1020725	NM 5570 4477	Domestic	Septic tank	-	10	Aros River
CAR/R/1013679	NM 5764 4351	Domestic	Septic tank	-	<15	Land
CAR/R/1019269	NM 5806 4301	Domestic	Septic tank	-	5	Land
CAR/R/1016603	NM 5807 4301	Domestic	Septic tank	-	5	Land
CAR/R/1016709	NM 5930 4282	Domestic	Septic tank	-	5	Unnamed watercourse
CAR/R/1025499	NM 5944 4287	Domestic	Septic tank	-	50	Land
CAR/R/1014593	NM 5998 4278	Domestic	Septic tank	-	5	Land
CAR/R/1017784	NM 5620 4200	Domestic	Septic tank	-	10	Land
CAR/R/1011058	NM 5709 4240	Domestic	Septic tank	-	5	Allt Na Searmoin
WPC-C-W12124	NM 572 435	Domestic	Septic tank	-	-	Salen Bay

The majority of these discharge to land via soakaway systems. 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 of Salen Bay are presented in Table 4.3.

Table 4.3 Discharges and septic tanks observed during shoreline survey

No.	Date	Grid Reference	Observation
1	17/06/2008	NM 57532 43240	Houses with private septic tanks
2	17/06/2008	NM 57703 43636	Possible septic tank, no signage
3	17/06/2008	NM 57656 43753	Septic tank outfall
4	17/06/2008	NM 57149 43446	Outfall pipe, at least 7 concrete pipe casing sections, with 5m between each
5	17/06/2008	NM 57177 43199	Corner of septic tank works (Salen ST)
6	17/06/2008	NM 57164 43176	Other corner of Salen ST. Public convenience adjacent
7	17/06/2008	NM 56054 44872	House with discharge pipe

At the settlement of Salen, two community septic tanks discharge to Salen Bay. The largest of these (Salen septic tank, WPC-C-W12124) has a consented dry weather flow (DWF) of 47 m^3/day, roughly equivalent to a population of 250-300. The main outfall for this lies in the middle of Salen Bay, in about 5m of water. There is also a CSO/EO for this septic tank, which discharges to the shoreline. It is uncertain how often this intermittent discharge operates. Kay et al (2008) found the mean level of *E. coli* in septic tank treated effluent to be 7.2×10^6 cfu/100ml under dry conditions. Assuming a maximum flow of 47 m^3/day, the maximum estimated loading contributed by this discharge during dry weather is 3.4×10^{12} *E. coli* / day. The other communal septic tank (Ardmore Road) has a maximum consented DWF of 3 m^3/day and discharges close to the low water mark at the south east end of Salen Bay. This contributes a maximum estimated loading of 2.2×10^{11} *E. coli* / day

SEPA lists a further 13 private discharge consents for septic tanks in the area shown in Figure 4.1. The majority of these (9 of the 13) discharge to soakaway, so should be of minimal importance to levels of contamination at the fishery. One (CAR/R/1020597) has a partial soakaway on the shore just north of Sound of Mull: Aros, so may discharge to the shore here from time to time. One discharges to an unnamed watercourse south of Salen, and another discharges to Allt Na Searmoin, which in turn discharges to the south end of Sound of Mull: Aros. Of greatest relevance to the fishery CAR/R/1020725, a domestic septic tank with a population equivalent of 10, which discharges to Aros River immediately upstream of where it enters the production area.

In addition to these, the shoreline survey identified that there were some private septic tanks at houses near the shore at Salen (1), confirmed the locations of the Ardmore road septic tank (2 & 3) and the Salen septic tank (4 - 6). The Salen septic tank was noted to possibly be susceptible to flooding from an adjacent stream. A further private discharge to the shore in close proximity to the fishery serving one house was also observed (7).

Figure 4.1 Sewage discharges at Sound of Mull: Aros

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 blue indicate freely draining soils, whereas areas shaded red indicate more poorly draining soils.

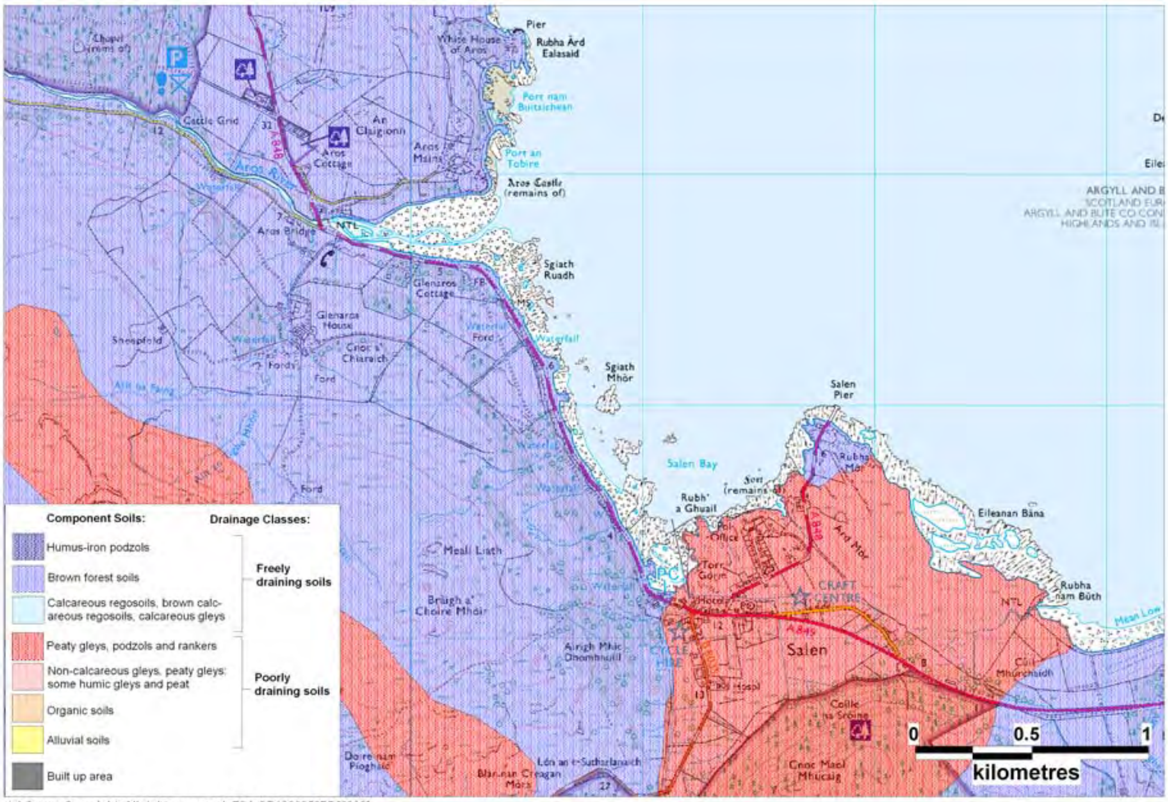

Figure 5.1 Component soils and drainage classes for Sound of Mull: Aros.

There are two types of component soils in this area: Brown forest soils and peaty gleys, podzols and rankers. Brown forest soils predominate and are found along most of the coastline and much of the area inland of Aros. Brown forest soils are freely draining, so surface runoff will be lower and the effectiveness of septic tank soakaway systems function more effectively in areas with these soils. Peaty gleys, podzols and rankers are present along the southeastern coastline around the town of Salen and also further inland along a strip running northwest to southeast. These soils are poorly draining, increasing the likelihood of surface water runoff and also reducing the effectiveness of soakaway systems.

The potential for runoff contaminated with *E. coli* from human and/or animal waste should therefore be low along most of the shoreline and immediately adjacent to the fishery at Aros, though higher around the town of Salen.

6. Land Cover

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

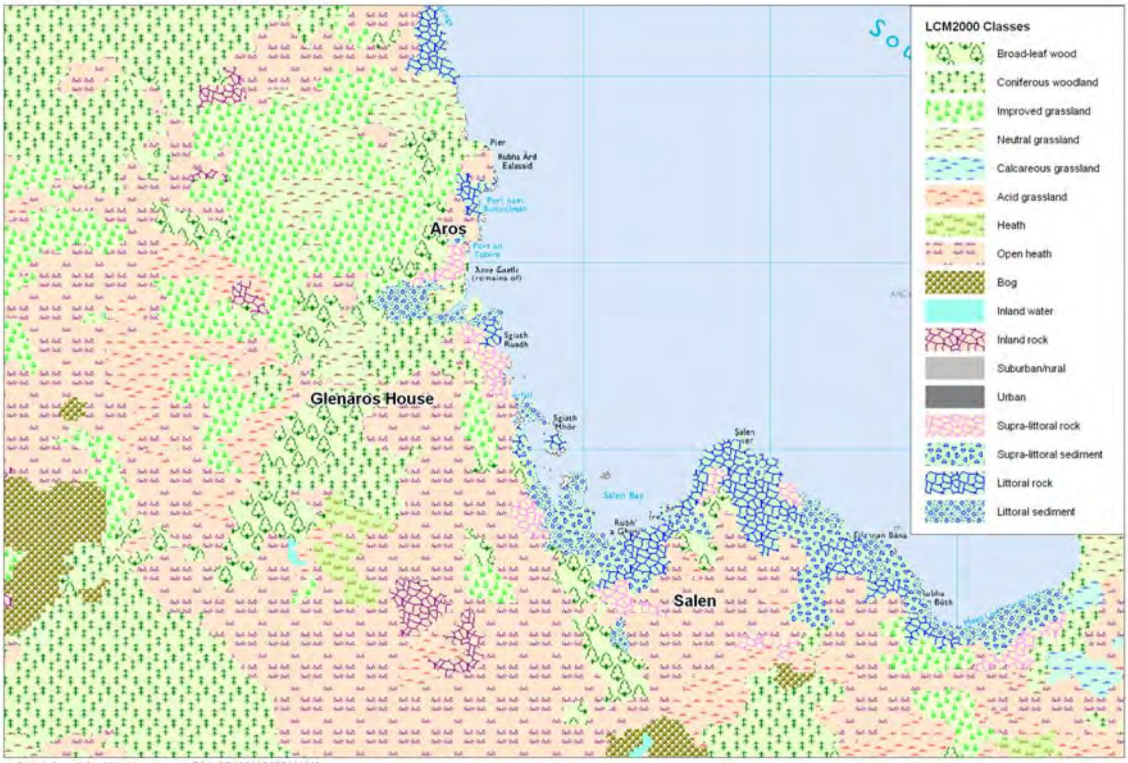

Figure 6.1 LCM2000 class land cover data for Sound of Mull: Aros

Land cover along the coastline of the Sound of Mull is primarily littoral rock, supra-littoral sediment and littoral sediment and is then replaced by open heath, improved grassland, coniferous woodland and broad-leaf wood further inland. There are also smaller areas of supra-littoral rock, inland rock, heath, acid grassland, neutral grassland and bog. Although the LCM2000 data does not highlight it, there are urban/suburban areas at Salen. There is good agreement between Figure 6.1, the ordnance survey map, and observations made during the shoreline survey.

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, a significant contribution of contaminated runoff from the improved pastures bordering the Aros River may be expected following heavy rainfall, particularly considering that this ground is fairly steeply sloping. However, this would be mitigated somewhat by the freely-draining soils found there. Further contaminated runoff could be expected from the developed area around Salen, however the river constitutes a more significant impact to the fishery.

7. Farm Animals

Agricultural census data was requested and received from the Scottish Government Rural and Environmental Research and Analysis Directorate (RERAD). The data was provided to parish level for 2008. Sound of Mull: Aros borders on two parishes: Torosay to the south with an area of 365 km^2, and Kilninian and Kilmore to the north, with an area of 307 km^2. Together, these two parishes cover approximately two thirds of the Isle of Mull. Recorded livestock populations for the parishes for 2008 are presented 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. This does not mean there are insignificant numbers of animals, only that they are present on only a few farms.

Table 7.1 Livestock numbers in Kilninian & Kilmore and Torosay Parishes, 2008

	Kilninian and Kilmore (307 km^2)		Torosay (365 km^2)	
	Holdings	Numbers	Holdings	Numbers
Total Pigs	*	*	*	*
Total Poultry	17	393	8	197
Total Cattle	22	1373	13	899
Total Sheep	38	16543	16	13047
Horses used in Agriculture	*	*	0	-
Horses and Ponies	11	53	6	14

* Data withheld on basis of confidentiality

Because these figures relate to large parish areas, they are of relatively little use in assessing the potential impact of livestock contamination at the fishery. However, they do give an idea of the total numbers of livestock over the broader area. Sheep are the predominant type of livestock kept in the area, with a rough average of 435 animals per holding in Kilninian and Kilmore and 815 per holding in Torosay. Cattle are also present in significant numbers, with each holding having on average 65 animals over both parishes.

The only information specific to the area near the shellfishery was that obtained during the shoreline survey (see Appendix 8), which only relates to the time of the site visit on 17th June 2008. 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 date and is dependent upon the point of view of the surveyor so some animals may have been obscured from view by the terrain.

The shoreline survey identified that sheep grazed in one specific area at the time. A large group of sheep (roughly 140) were present on fields around the mouth of the River Aros on the north-western shoreline. Geographical spread of contamination at the shores of the bay is therefore likely to be concentrated in this area, and will be carried into the production area primarily via the River Aros and thus immediately onto the current shellfish trestles.

There is no local information available for the area surrounding Sound of Mull: Aros concerning the seasonal numbers of livestock, but Argyll and Bute Council advise that an increase in numbers following lambing in the spring would be expected, and numbers would then decrease from autumn as animals are sent to market. An annual livestock show is held for one day in August on a pasture adjacent to the Aros River at Aros Bridge. This would probably provide a flush of faecal bacteria from the show area to the fishery, though it would be confined to a limited period during and immediately after the show and so would be of limited duration.

Figure 7.1 Livestock observations at Sound of Mull: Aros

8. Wildlife

A survey conducted by the Sea Mammal Research Unit in 2000 estimated a population of 1616 common seals on Mull. The exact locations of the haul out sites were not specified, so it is uncertain whether they reside in the vicinity of Sound of Mull: Aros. No seals were seen during the course of the shoreline survey, but they are reported to haul out on sands near Aros. Seals will forage widely for food and it is likely that seals will feed near the shellfishery at some point in time. The population is relatively small in relation to the size of the area concerned and is highly mobile therefore it is likely that any impact will be limited in time and area and unpredictable.

Within the Sound of Mull it is likely that cetaceans may be present from time to time, especially the smaller species. Their presence, however, is likely to be fleeting and unpredictable.

Seabird populations were investigated all over Britain as part of the SeaBird 2000 census. The area was surveyed in sections on various dates in late spring of 2000. Total counts of all species recorded within 5 km of the trestles are presented in Table 8.2. Most counts were of occupied nesting sites, so actual numbers of seabirds breeding in the area will be approximately double.

Table 8.2 Seabird counts within 5km of the site

Common name	Species	Count	Method
Herring gull	Larus argentatus	142	Occupied nests
Great Black-backed Gull	Larus marinus	40	Occupied territory
Shag	Phalacrocorax aristotelis	35	Occupied nests
Common gull	Larus canus	24	Occupied territory/nests
Black guillemot	Cepphus grylle	5	Individuals on land

The largest concentration of breeding seabirds by far was at Eilianan Glasa, a small rocky island in the middle of the Sound of Mull about 3 km to the east of the trestles, where 35 shag, 40 great black backed gull and 142 herring gull nests/territories were recorded. This colony is probably too far away from the shellfishery to have a significant impact on the bacteriological quality of the shellfish. Only two pairs of common gulls were recorded within the production area. A few small groups of gulls were observed in the bay during the course of the shoreline survey. Though nesting occurs in early summer and after this some species will then disperse, the gulls are likely to be present in the area throughout the year.

Waterfowl (ducks and geese) are likely to be present in the area at various times, primarily to overwinter, or briefly during migration, although some species breed on Mull in small numbers. Around 20-30 geese were observed during the course of the shoreline survey (June) suggesting there is a small breeding population in the area. Geese would tend to be found grazing on farm fields and open grassland such as the pastures near the shores of the production area.

Wading birds would be concentrated on intertidal areas, such as the area on which the trestles are located. A few oystercatchers and other waders were observed in the bay during the course of the shoreline survey, but not in large concentrations.

Deer will be present particularly in wooded areas where the habitat is best suited for them. Parts of the shoreline of the production area are wooded, and there are extensive managed woodlands further inland. While no population data were available for this specific area, it can be presumed that they host populations of deer. The Deer Commission for Scotland report a count of 1011 red deer and 1 roe deer for the whole of Mull, the total area of which is approximately 950 km^2. Therefore the overall density of about 1 deer per km^2 is low relative to that of livestock.

No otters were seen during the course of the shoreline survey, although it is likely that they are present in the area, albeit at low densities. Given their low population density their impacts on the shellfishery will be very minor.

In summary, potential wildlife impacts to the production area include geese and other waterbirds, deer, seals and otters. Geese grazing on the pastures may constitute a source of diffuse contamination in the same manner as livestock, but their impacts will be minor relative to livestock based on the numbers seen during the shoreline survey, and less predictable as they are free to move around more widely. Impacts from the other wildlife species are likely to be of less significance, and more localised and unpredictable.

9. Meteorological Data

The nearest weather station is located at Gruline, approximately 4 km southwest of the production area. Rainfall data was supplied for the period 01/01/03 to 31/12/2007 (total daily rainfall in mm). Data was unavailable for September 2004. It is likely that the rainfall experienced at Gruline is very similar to that experienced at the production area due to their close proximity.

The nearest major weather station where wind is measured is located at Tiree, approximately 56 km to the west of the production area. Wind direction was recorded at 3 hourly intervals for the majority of the period 1/1/1996 to 31/12/2007. Wind patterns may differ between these two locations due to their distance apart and the effects of local topography. However, it was considered that wind readings at Tiree would be more representative than those from Glasgow for the Isle of Mull.

This section aims to describe the local rain and wind patterns and how they may affect the bacterial quality of shellfish at Sound of Mull: Aros.

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 wastewater treatment plant overflows (e.g. Mallin et al, 2001; Lee & Morgan, 2003).

Total annual rainfall and mean monthly rainfall were calculated, and are presented in Figures 5.1 and 5.2.

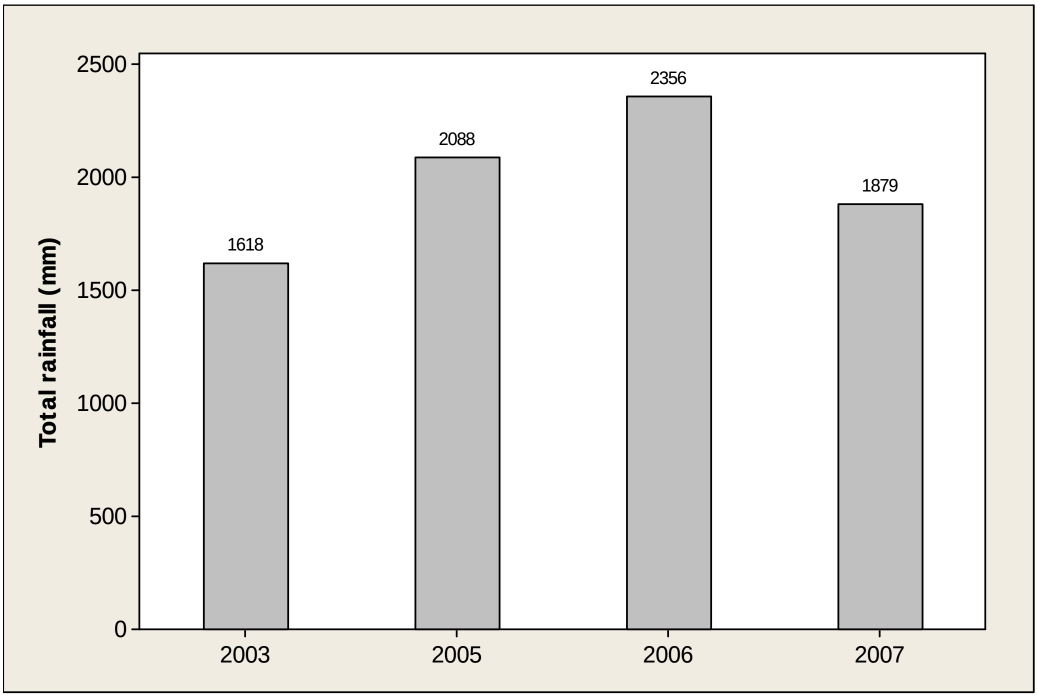

Figure 9.1 Total annual rainfall at Gruline 2003 – 2007 (2004 omitted as dataset incomplete)

There was marked variability in annual total rainfall, with a 46% increase between 2003 and 2006, then a 20% decrease between 2006 and 2007, indicating that the impact of rainfall-dependent contamination on water quality in the area may also vary considerably from year to year.

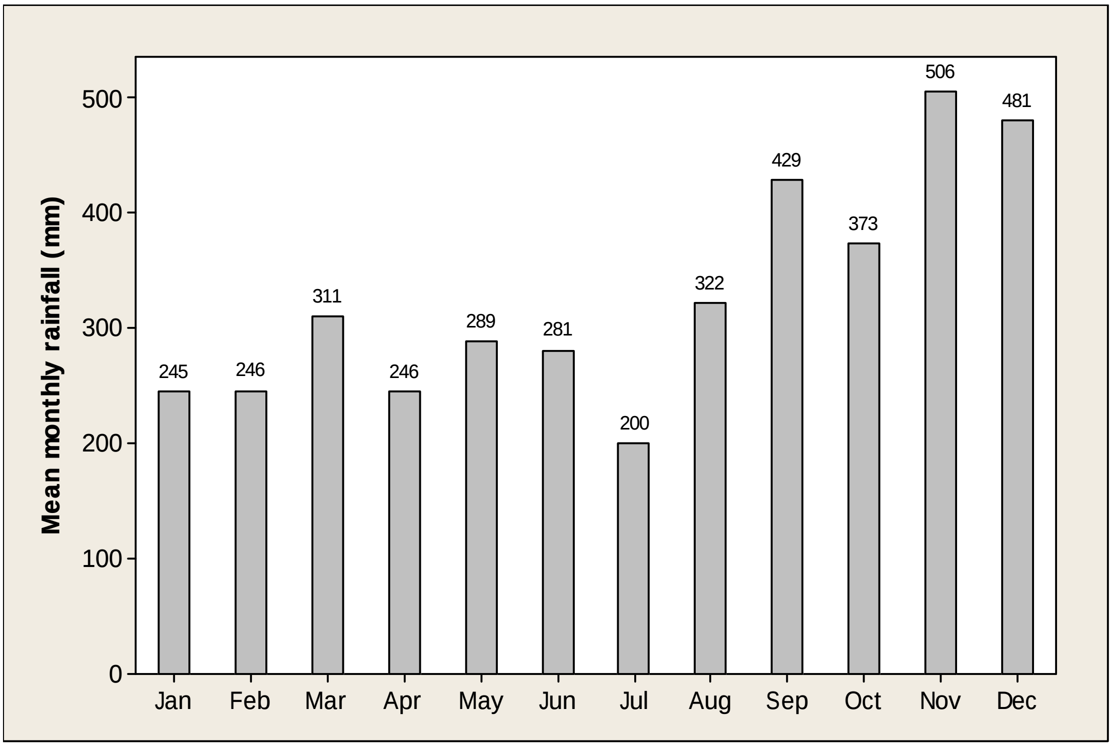

Figure 9.2 Mean total monthly rainfall at Gruline 2003 – 2007

The wettest months were September through December. For the period considered here (2003 – 2005), 23% of days had no rainfall and 43% had rainfall of 1 mm or less.

It is anticipated that levels of rainfall dependant faecal contamination entering the production area from these sources will be higher during the autumn and early winter months.

Periods of increased rainfall are generally associated with higher levels of contaminated surface water runoff. However, contamination from these sources may be present at any time of year after a heavy rainfall.

9.2 Wind

Wind data collected at the Tiree weather station is summarised by season and presented in Figures 9.3 to 9.7. This weather station was selected as it was the closest to Sound of Mull: Aros, and is also located within the Western Isles. Wind patterns at Tiree are, however, likely to differ somewhat from those found at Sound of Mull: Aros, as Tiree is more exposed to the open Atlantic and local topography is likely to channel winds along the Sound of Mull.

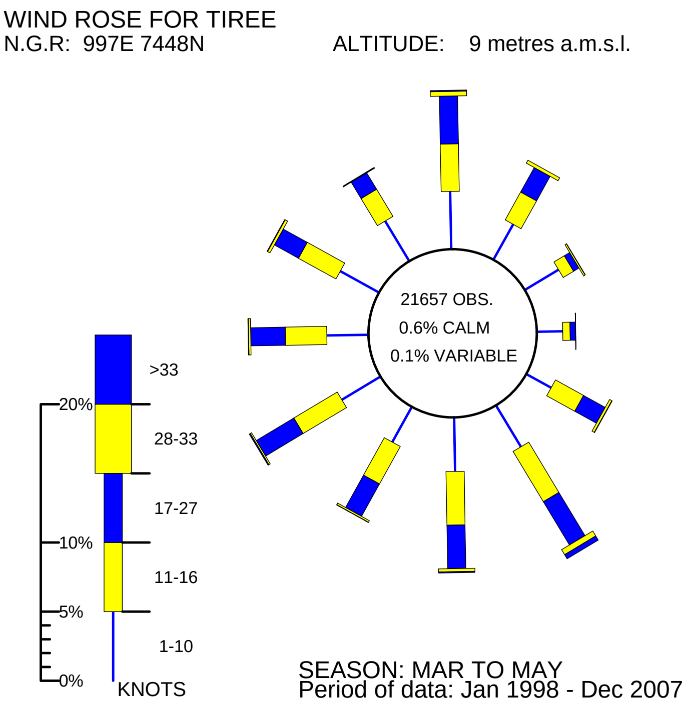

Figure 9.3 Wind rose for Tiree (March to May)

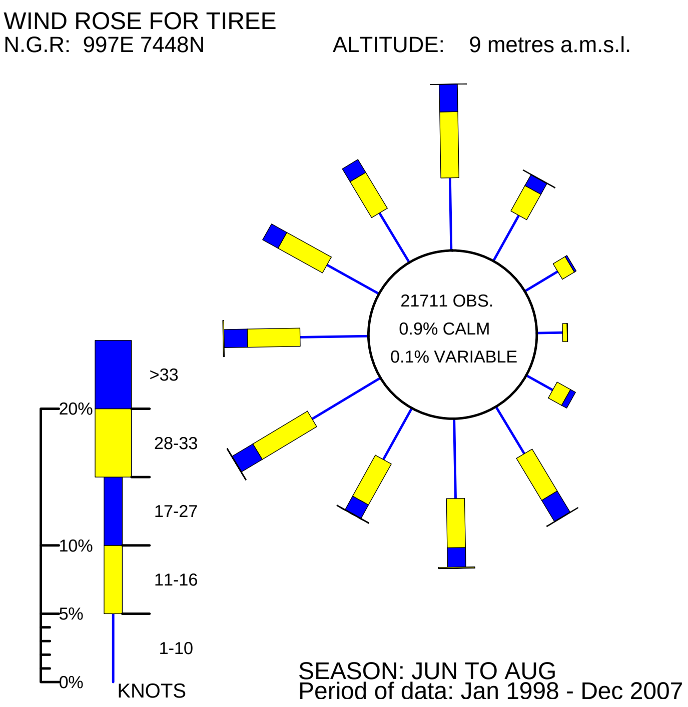

Figure 9.4 Wind rose for Tiree (June to August)

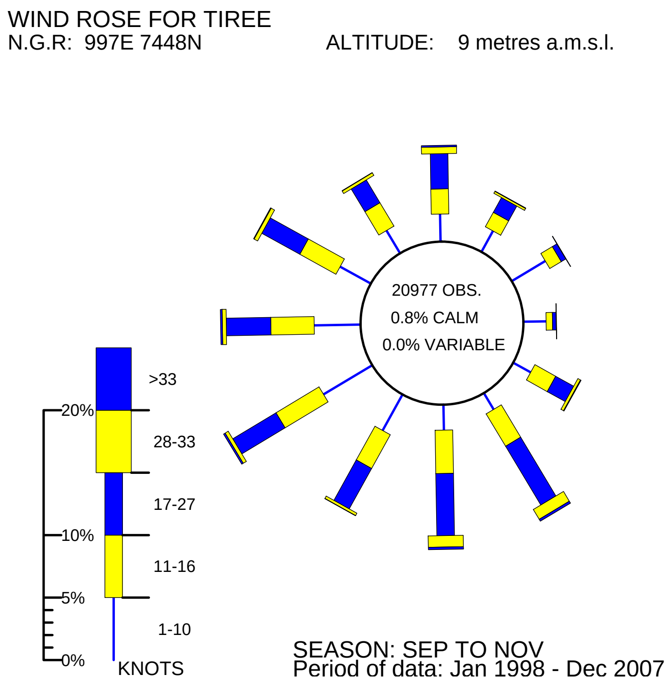

Figure 9.5 Wind rose for Tiree (September to November)

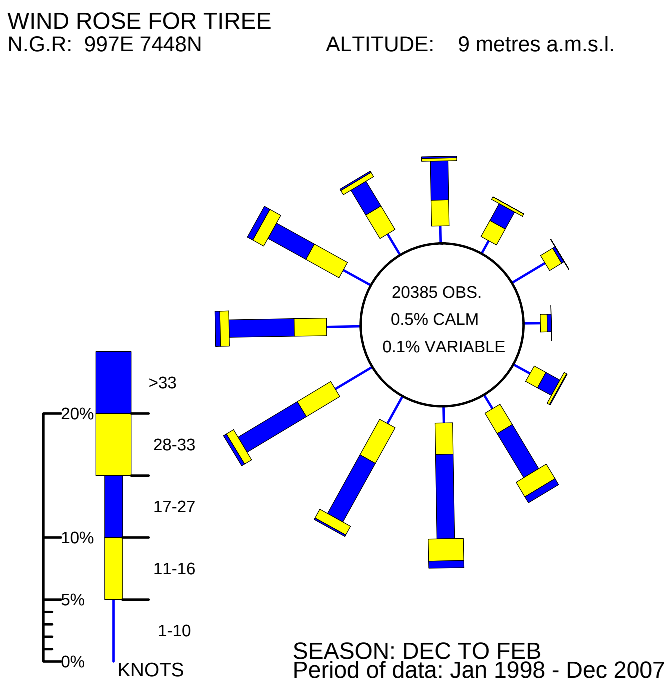

Figure 9.6 Wind rose for Tiree (December to February)

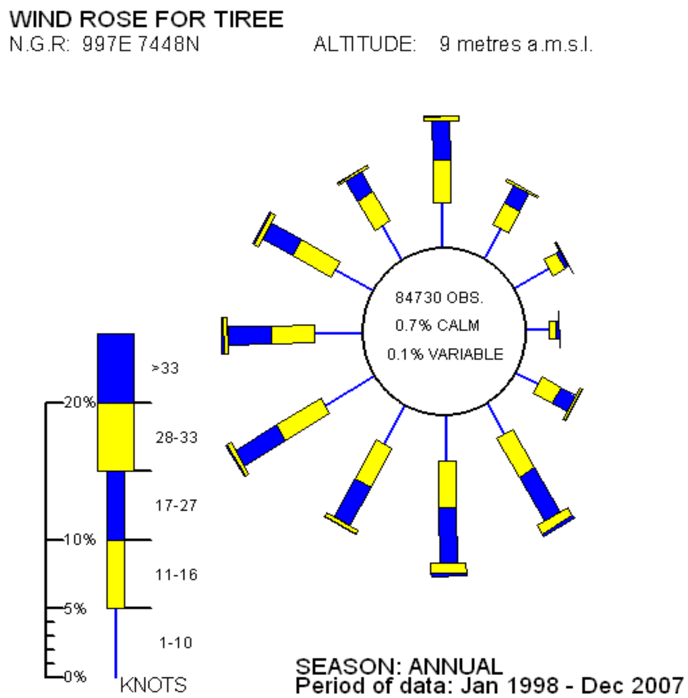

Figure 9.7 Wind rose for Tiree (All year)

The prevailing wind direction at Tiree is from the south and west, but wind direction often changes markedly from day to day with the passage of weather systems. Winds are lightest in the summer and strongest in the winter.

Sound of Mull: Aros lies in a small bay on the east coast of Mull. It is exposed to winds blowing in from the Sound of Mull from both a northerly and easterly direction. The sound of Mull itself has a north west to south east aspect, and is approximately 4 km wide at this point. The land to the south and west rises to over 150 m in places, providing some shelter from winds from these directions. 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. Therefore strong winds may significantly alter the pattern of surface currents within the bay and the Sound of Mull, subsequently affecting the movement of freshwater-associated contamination.

Strong winds may affect tide height depending on wind direction and local hydrodynamics. A strong wind combined with a spring tide may result in higher than usual tides, which will carry accumulated faecal matter from livestock, in and above the normal high water mark, into the production area. An onshore wind will result in increased wave action, which may resuspend any organic matter settled in the substrate.

10. Current and historical classification status

Sound of Mull: Aros has not yet been classified for Pacific oysters. It has, however, been classified for the harvest of wild mussels since 2003. This was initiated by the harvester to investigate the likely classification Pacific oysters would receive in the area. The classification history is presented in Table 10.1. For the bulk of the period classified, the area received a B classification, although in 2004 and 2009 it received a seasonal A/B classification. The official RMP for shore mussels lies within the production area in the intertidal zone, approximately 260 m from the oyster trestles. A map of the current mussel production area is presented in Figure 10.1. There is no Crown Estates lease associated with this production area.

Table 10.1. Classification history, Sound of Mull: Aros, shore mussels

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003	B	B	B	B	B	B	B	B	B	B	B	B
2004	A	B	B	B	B	B	B	B	B	B	B	A
2005	B	B	B	B	B	B	B	B	B	B	B	B
2006	B	B	B	B	B	B	B	B	B	B	B	B
2007	B	B	B	B	B	B	B	B	B	B	B	B
2008	B	B	B	B	B	B	B	B	B	B	B	B
2009	B	A	A									

In general, mussels located at the same point as Pacific oysters will tend to yield higher *E. coli* results (Younger *et al.* 2003).

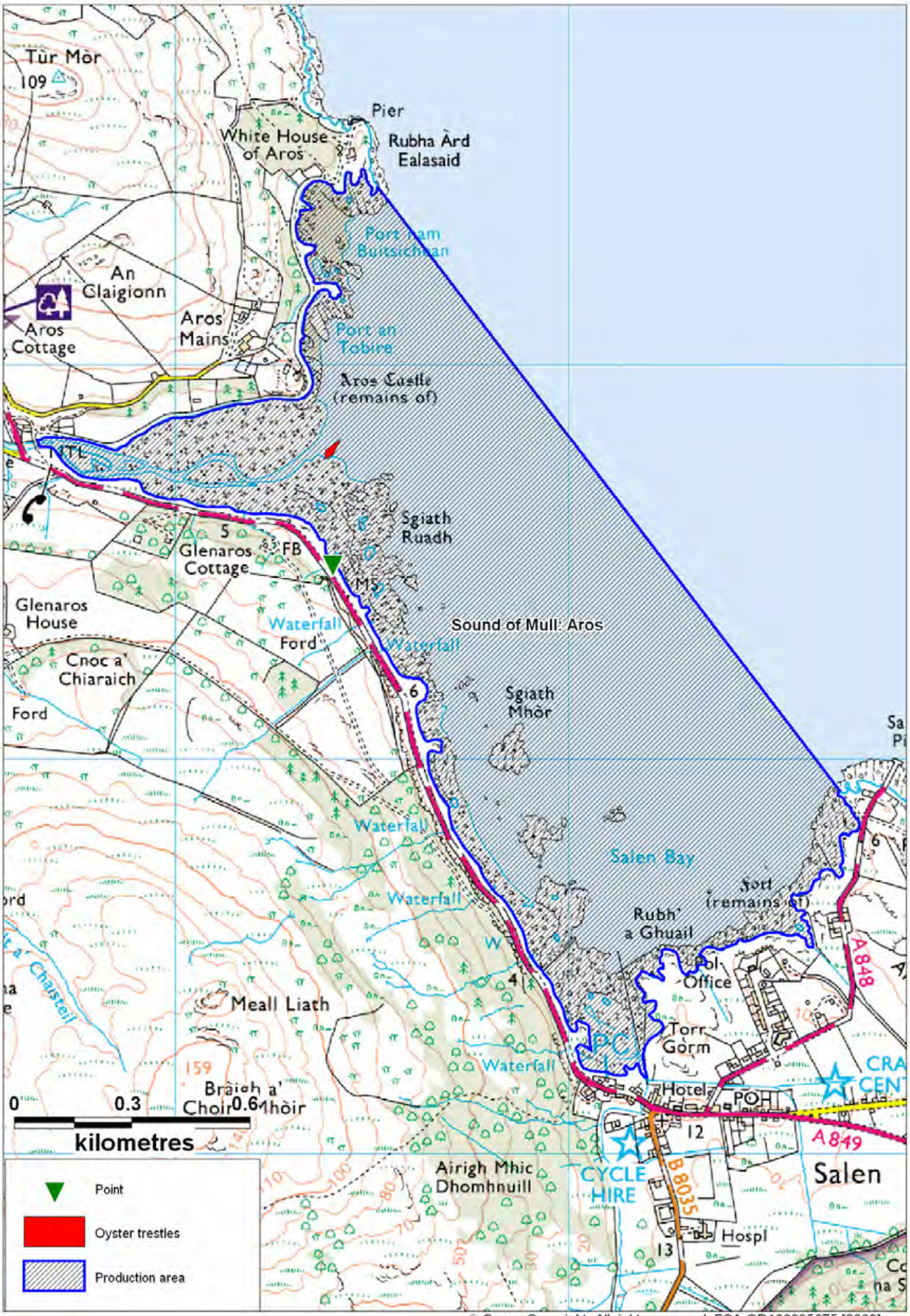

Figure 10.1 Current production area (wild mussels)

11. Historical *E. coli* data

11.1 Validation of historical data

All shellfish samples taken from Sound of Mull: Aros from the beginning of 2002 up to the end of 2007 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 an invalid test result and were excluded from the analysis. No samples were rejected on the basis of major geographical or sampling date discrepancies. 46 samples had a reported sampling location of NM564445 (the RMP), which falls 2m outside the production area boundaries. These were included in the analysis as they were within the 100m tolerance associated with estimating a grid reference from an Ordnance Survey map.

Two 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 by production area

A summary of all sampling and results by is presented in Table 11.1. As noted in Section 10, in general, mussels located at the same point as Pacific oysters will tend to yield higher *E. coli* results.

Table 11.1 Summary of historic *E. coli* monitoring results, Sound of Mull: Aros shore mussels

Production area	Sound of Mull: Aros	Sound of Mull: Aros	Sound of Mull: Aros	Sound of Mull: Aros	Sound of Mull: Aros	Sound of Mull: Aros	Sound of Mull: Aros	Sound of Mull: Aros
Site	Aros	Aros	Aros	Aros	Aros	Aros	Aros	Aros
Species	Common mussels	Common mussels	Common mussels	Common mussels	Common mussels	Common mussels	Common mussels	Common mussels
SIN	AB-257-75-8	AB-257-75-8	AB-257-75-8	AB-257-75-8	AB-257-75-8	AB-257-75-8	AB-257-75-8	AB-257-75-8
Location	NM564445	NM5631144675	NM56324467	NM5635544690	NM5636644662	NM5641444633	NM5633144675	NM5643444830
Total no of samples	47	1	2	1	1	1	1	1
No. 2002	8	0	0	0	0	0	0	0
No. 2003	10	0	0	0	0	0	0	0
No. 2004	11	0	0	0	0	0	0	0
No. 2005	9	0	0	0	0	0	0	0
No. 2006	8	0	0	0	0	0	0	0
No. 2007	1	1	2	1	1	1	1	1
Minimum	<20		750					
Maximum	3500		750					
Median	290	16000		20	750	700	1700	70
Geometric mean	236							
90 percentile	1300							
95 percentile	1700							
No. exceeding 230/100g	24 (51%)							
No. exceeding 1000/100g	10 (21%)							
No. exceeding 4600/100g	0 (0%)							
No. exceeding 18000/100g	0 (0%)							

11.3 Overall geographical pattern of results

Figure 11.1 presents a map of geometric mean result by sampling location. Aside from NM564445, where 47 samples were collected, all other sampling points were only sampled on one or two occasions. All samples were collected from a relatively small area. Samples reported from NM564445 were collected before the start of the OC sampling programme. All other samples were collected after the start of the OC sampling programme in 2007, when accurate sampling locations were recorded using a GPS. No particular geographic pattern in levels of contamination is discernable.

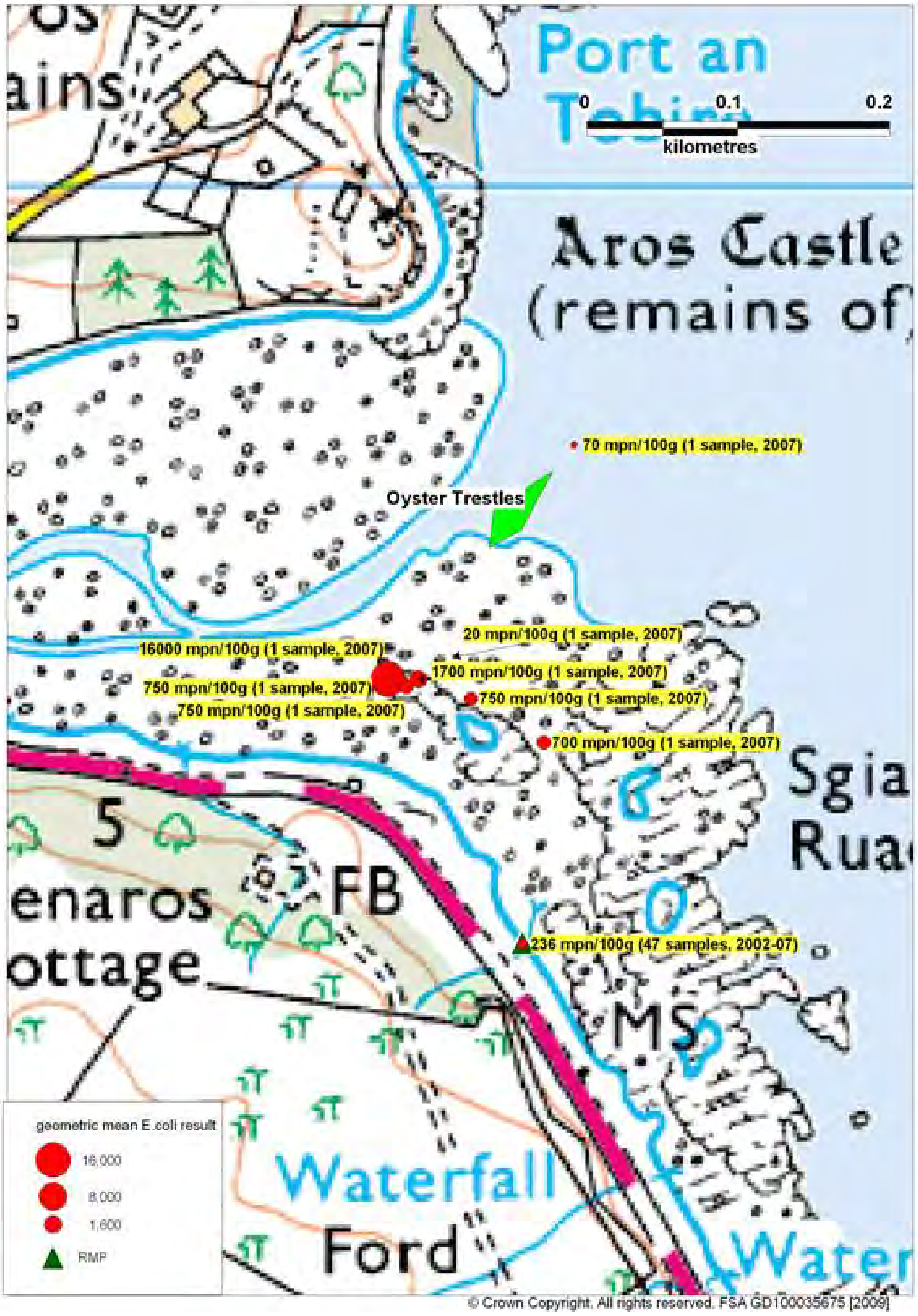

Figure 11.1 Geometric mean *E. coli* result by reported sampling location

11.4 Overall temporal pattern of results

Figures 11.2 and 11.3 present scatter plots of individual results against date for all samples taken from. Both are fitted with trend lines to help highlight any apparent underlying trends or cycles. Figure 11.2 is fitted with lines indicating the geometric mean of the previous 5 samples, the current sample and the following 6 samples. Figure 11.3 is fitted with a loess smoother, a regression based smoother line.

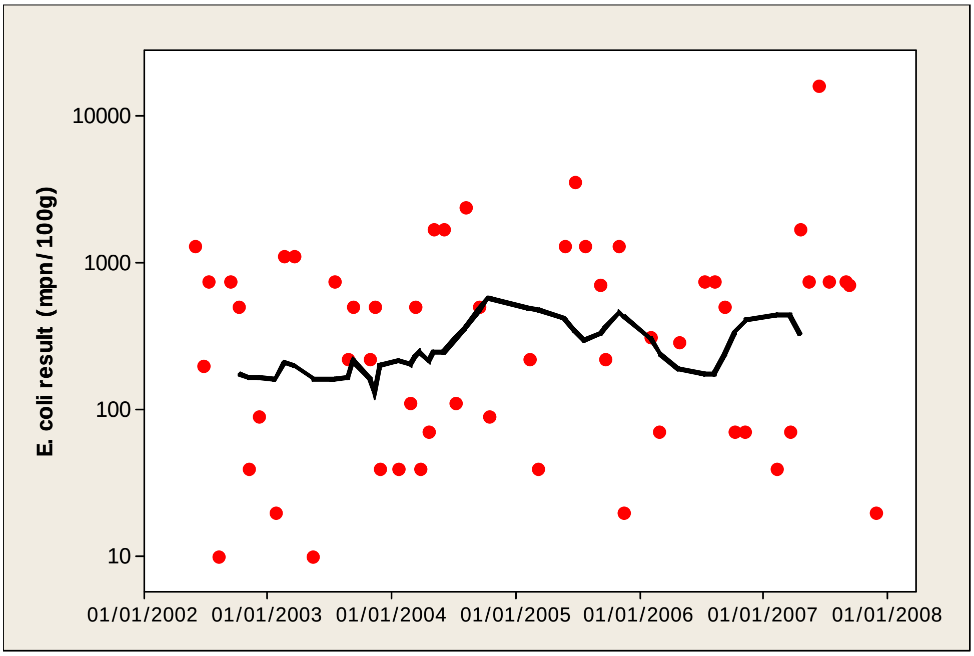

Figure 11.2 Scatterplot of *E. coli* results by date with rolling geometric mean

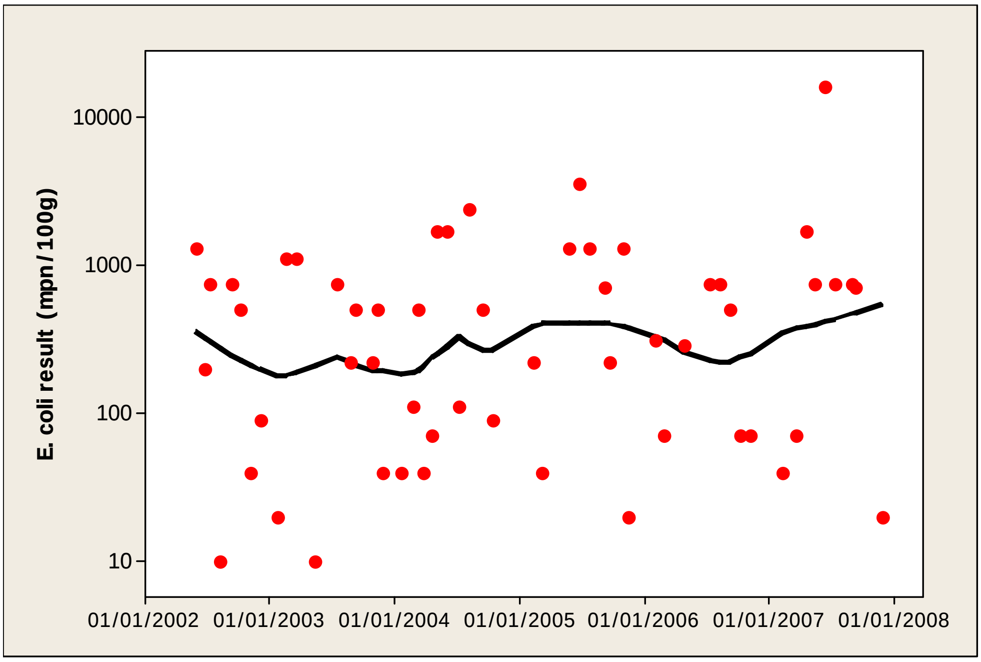

Figure 11.3 Scatterplot of *E. coli* results by date with loess smoother

While there is no clear trend apparent in the above figures, there does appear to be an increase in maximum result over this period.

11.5 Seasonal pattern of results

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns of human occupation. All of these can affect levels of microbial contamination, and cause seasonal patterns in results. Figure 11.4 presents the geometric mean *E. coli* result by month (+ 2 times the standard error).

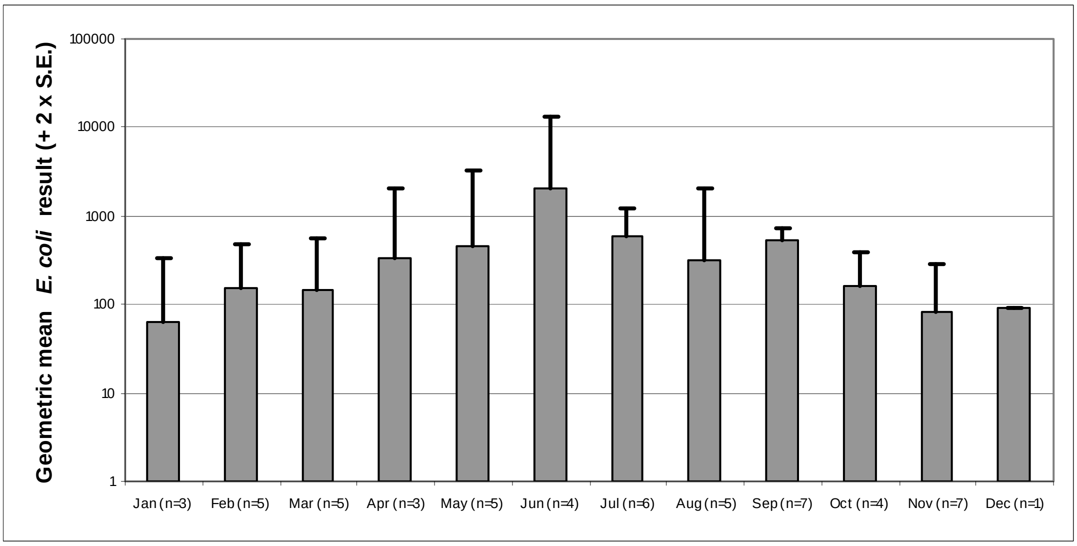

Figure 11.4 Geometric mean *E. coli* result by month

Results were highest in June, and lowest during the late autumn and early winter.

For statistical evaluation, seasons were split into spring (March - May), summer (June - August), autumn (September - November) and winter (December - February).

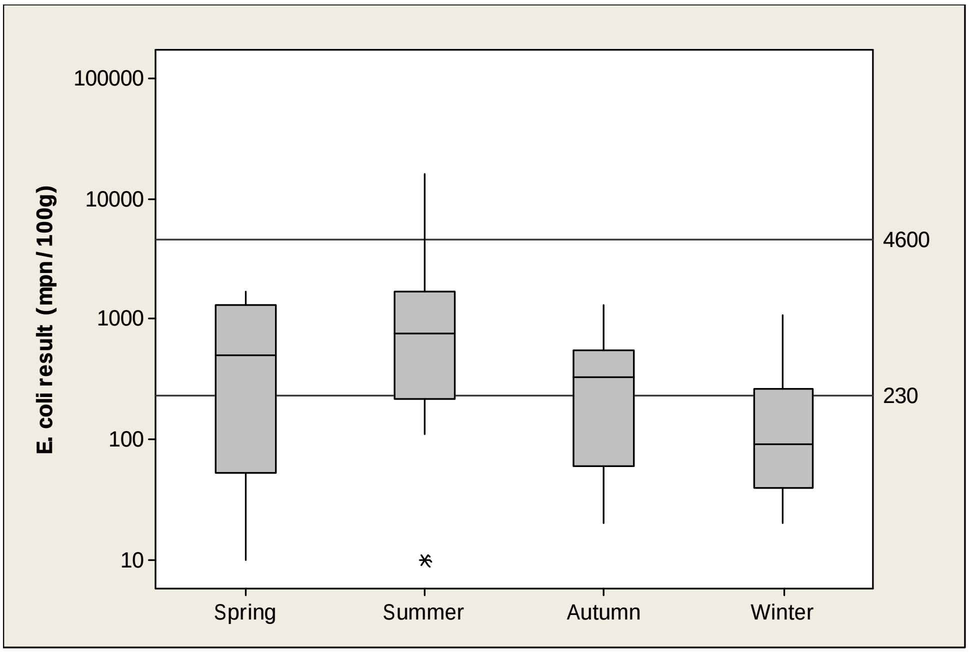

Figure 11.5 Boxplot of *E. coli* result by season

A significant difference was found between results by season (One-way ANOVA, p=0.033, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicates that results during the winter were significantly lower than results during the summer.

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

The nearest weather station is Gruline, 4 km south west of the production area. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2007 (total daily rainfall in mm). The coefficient of determination was calculated for *E. coli* results and rainfall in the previous 2 days at Gruline. Figure 11.6 presents a scatterplot of *E. coli* results against rainfall. Figure 11.7 presents a boxplot of results by previous 2 days rainfall quartile for both production areas (quartile 1 = 0 to 0.7 mm, quartile 2 = 0.7 to 6.2 mm, quartile 3 = 6.2 to 17 mm, quartile 4 = more than 17 mm).

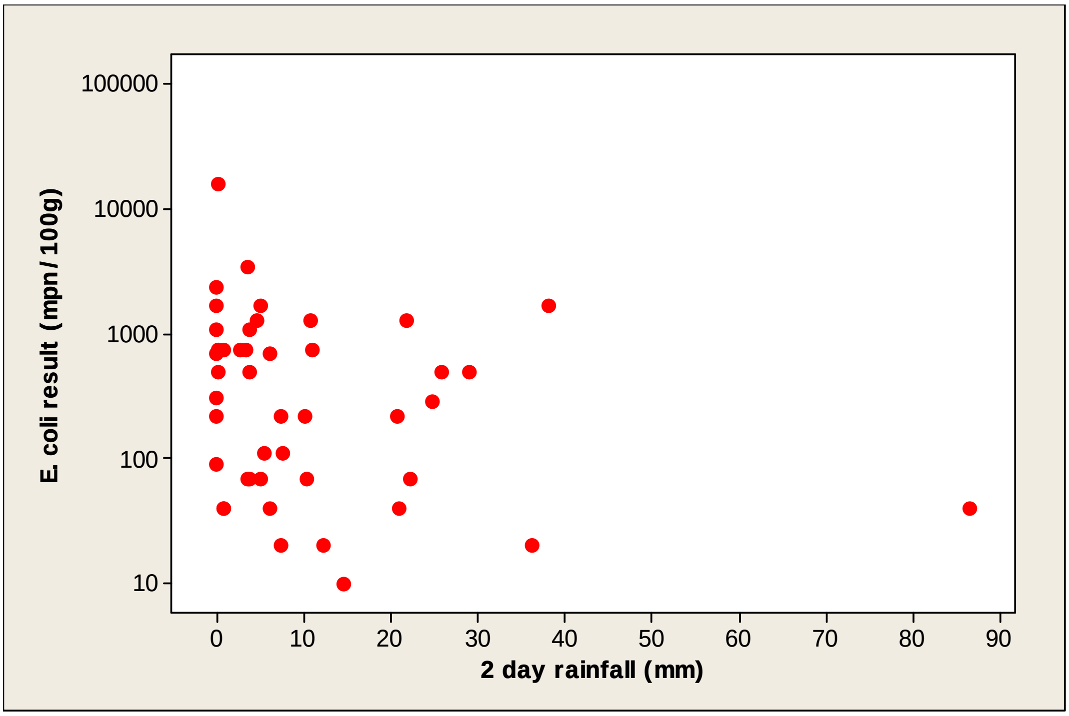

Figure 11.6 Scatterplot of *E. coli* result against rainfall in previous 2 days

The coefficient of determination indicates that there was no relationship between the *E. coli* result and the rainfall in the previous two days (Adjusted R-sq=4.7%, p=0.081, Appendix 6).

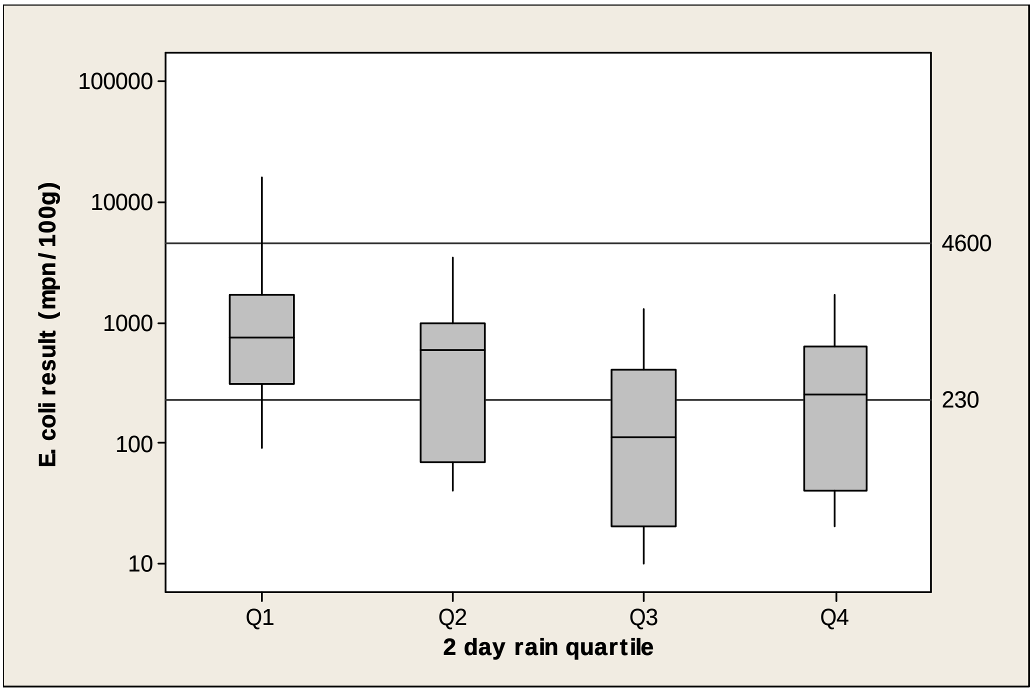

Figure 11.7 Boxplot of *E. coli* result by rainfall in previous 2 days quartile

A significant difference was found between the results for each 2-day rain quartile (One way ANOVA, p=0.034, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicates that results for quartile 3 are significantly lower than those for quartile 1.

As the effects of heavy rain may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationship between rainfall in the previous 7 days and sample results was investigated in an identical manner to the above. Interquartile ranges for 7 days rainfall were as follows; quartile 1 = 0 to 13.4 mm; quartile 2 = 13.4 to 32.4 mm; quartile 3 = 32.4 to 54.7 mm; quartile 4 = more than 54.7 mm.

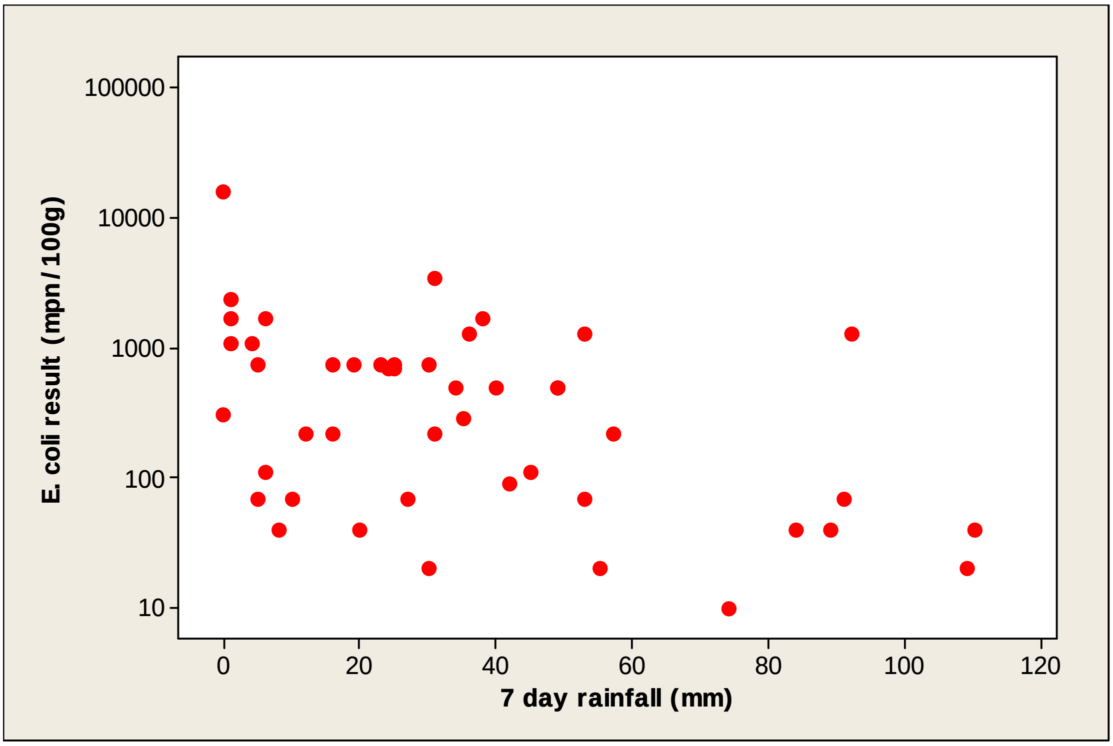

Figure 11.8 Scatterplot of *E. coli* result against rainfall in previous 7 days

The coefficient of determination indicates that there was a weak negative relationship between the *E. coli* result and the rainfall in the previous 7 days (Adjusted R-sq=19.9%, p=0.001, Appendix 6).

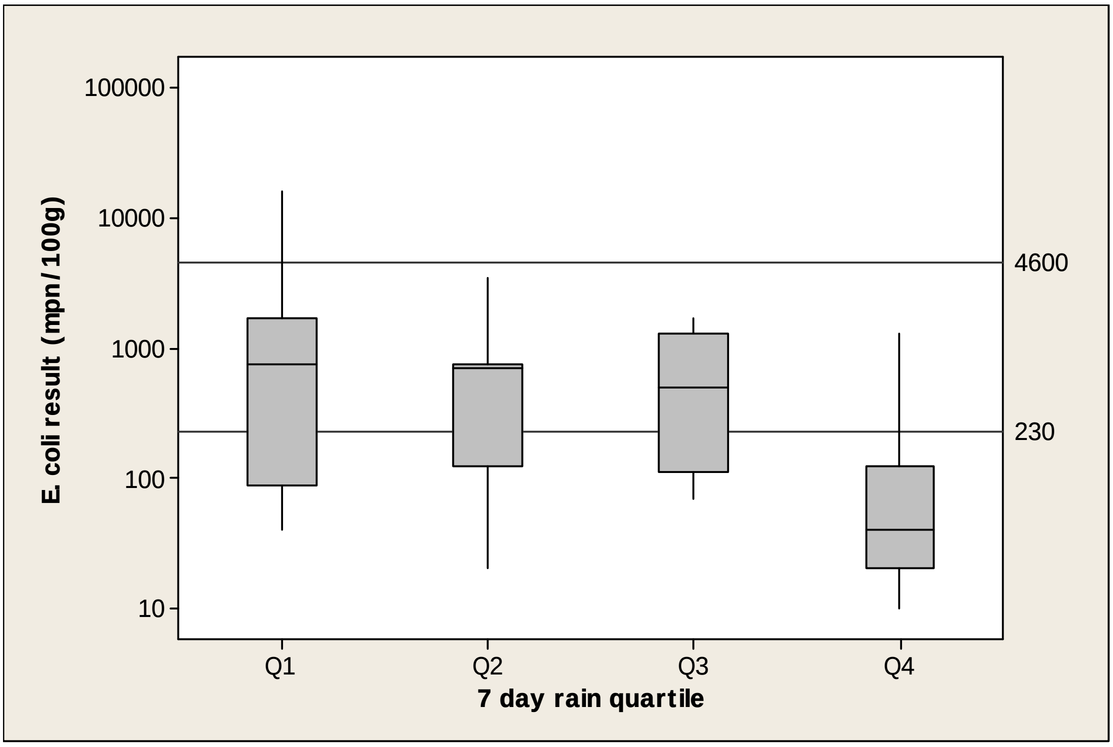

Figure 11.9 Boxplot of *E. coli* result by rainfall in previous 7 days quartile

A significant difference was found between the results for each 7-day rain quartile (One way ANOVA, p=0.007, Appendix 5). A post ANOVA test (Tukeys comparison, Appendix 6) indicates that results for quartile 4 were significantly lower than for all other quartiles.

11.6.2 Analysis of results by tidal size 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 production area.

However, as the mussels are found in the intertidal zone towards the low water mark, sampling was targeted at low water on the larger tides. Therefore it was not appropriate to investigate tidal effects.

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.

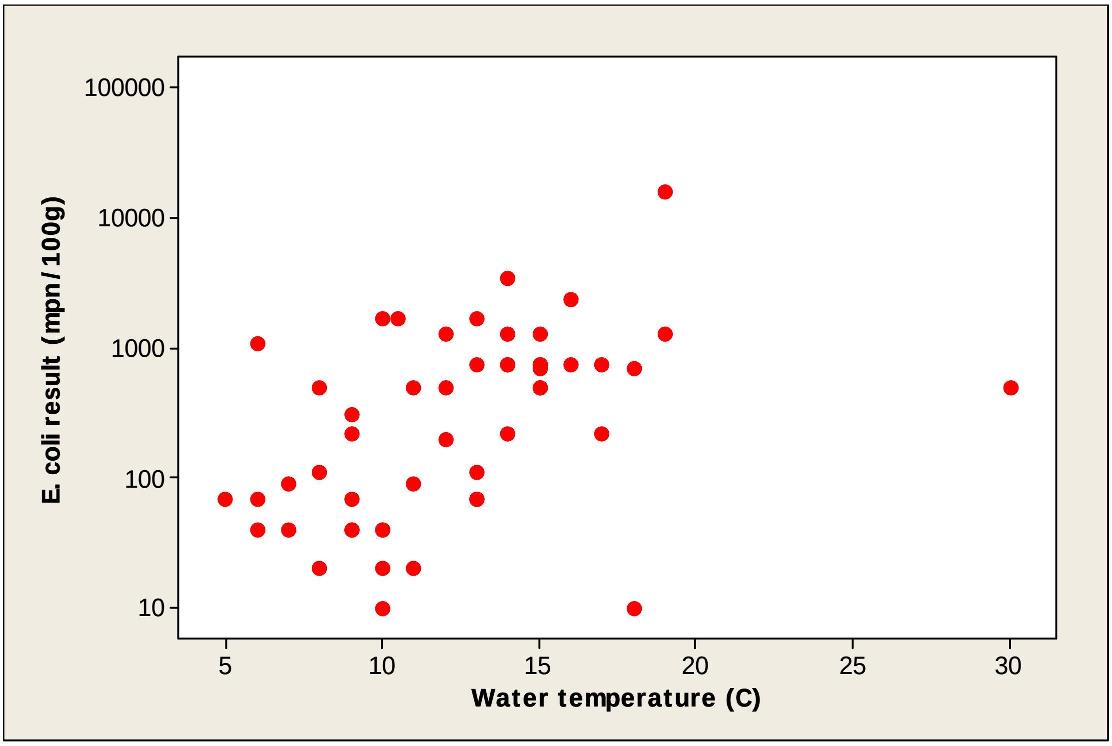

Figure 11.10 Scatterplot of *E. coli* result by water temperature

The coefficient of determination indicates that there was a weak positive relationship between the *E. coli* result and water temperature (Adjusted R-sq=18.2%, p=0.001, Appendix 6).

11.6.4 Analysis of results by wind direction

Wind speed and direction are likely to change water circulation patterns in the production area. The nearest major weather station where wind is measured is located at Tiree, approximately 56 km to the west of the production area.

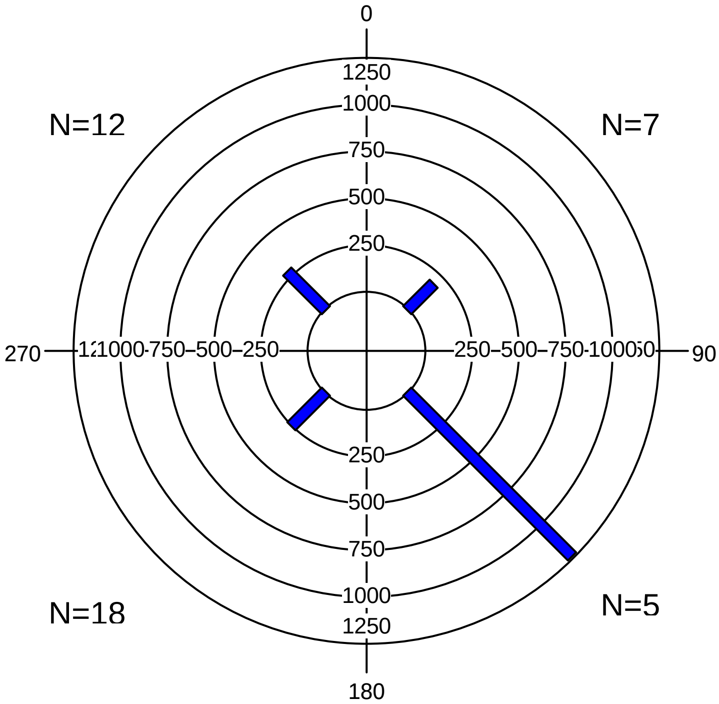

Figure 11.11 Circular histogram of geometric mean *E. coli* result by 7 day mean wind direction

A significant correlation was found between wind direction and *E. coli* result (circular-linear correlation, r=0.32, p=0.018, Appendix 6). Higher mean results occurred when the wind was in the south easterly quarter. It must also be noted that the majority of samples were collected during periods of westerly winds, and wind speeds were not taken into consideration.

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 11.12 presents a scatter plot of *E. coli* result against salinity, where salinity readings were available.

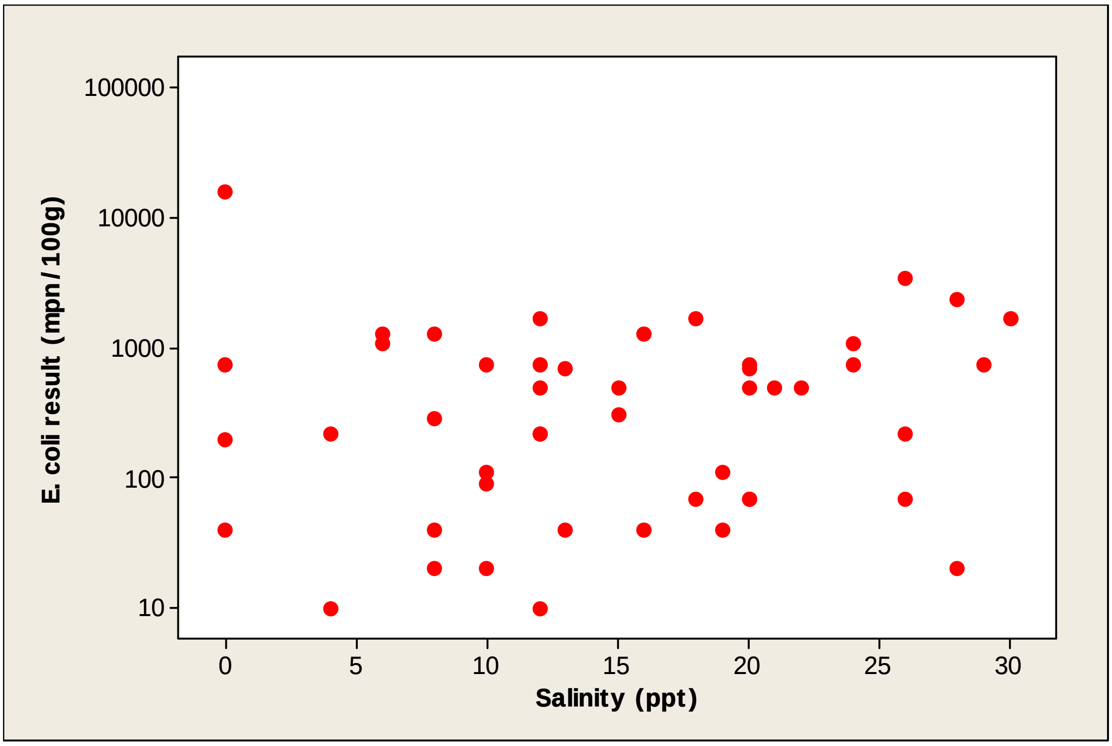

Figure 11.12. Scatterplot of *E. coli* result against salinity

The coefficient of determination indicates that there was a no relationship between the *E. coli* result and salinity (Adjusted R-sq=0.0%, p=0.428, Appendix 6). A wide range of salinities were recorded.

11.7 Evaluation of peak results

Three results over 2000 *E. coli* mpn/100g were reported. They were collected in August 2004, June 2005, and June 2007. All were collected after a period of light rainfall under varying wind directions.

Table 11.2 Historic *E. coli* sampling results over 1000 mpn/100g

Collection date	*E. coli* result (mpn/100g)	Location sampled	2 day rain quartile	7 day rain quartile	7 day wind direction	Time since high water	Height of previous tide
03/08/2004	2400	NM564445	Q1	Q1	176º	4h33min	3.9 m
21/06/2005	3500	NM564445	Q2	Q2	205º	6h22min	3.9 m
12/06/2007	16000	NM5631144675	Q1	Q1	16º	8h03min	3.8 m

11.8 Summary and conclusions

Given the distribution of reported sampling locations, it was not possible to investigate geographic differences in levels of contamination.

A seasonal effect was found, with mean results significantly higher in the summer compared to the winter. This is in agreement with the weak positive relationship between results and water temperature, and suggests that either inputs are higher in summer and/or the uptake of bacteria by the shellfish is higher in warmer water.

A weak negative relationship between results and rainfall in the previous 7 days was found. When rainfall quartiles were considered, results were significantly lower for 2 day quartile 3 compared to quartile 1, and results for 7 day quartile 4 were significantly lower than all other 7 day quartiles. This negative relationship is unexpected as generally higher rainfall results in more faecal contamination entering coastal waters via land runoff, and a river enters the production area adjacent to the sampling sites. However, if the source of contamination is steady under most conditions, heavy rainfall may dilute the concentration, leading to lower concentrations of *E. coli* in the shellfish. No relationship was found between shellfish *E. coli* results and salinity, however.

A correlation was found between result and wind direction. Highest average results occurred when the wind was blowing from the south east. The majority of point sources in the area are located to the south east of the sampling points, and the bay is exposed to the east.

It was not appropriate to investigate the effects of tide size (spring/neap) or tidal state (high/low/flood/ebb) on results as sampling was targeted at low water spring tides.

It should be noted that the relatively small amount of data precluded the assessment of the effect of interactions between environmental factors on the *E. coli* concentrations in shellfish.

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. This is not appropriate for this production area it has held a seasonal classification in the last three years.

12. Designated Shellfish Growing Waters Data

Sound of Mull: Aros does not lie within a designated shellfish growing water.

13. Bathymetry and Hydrodynamics

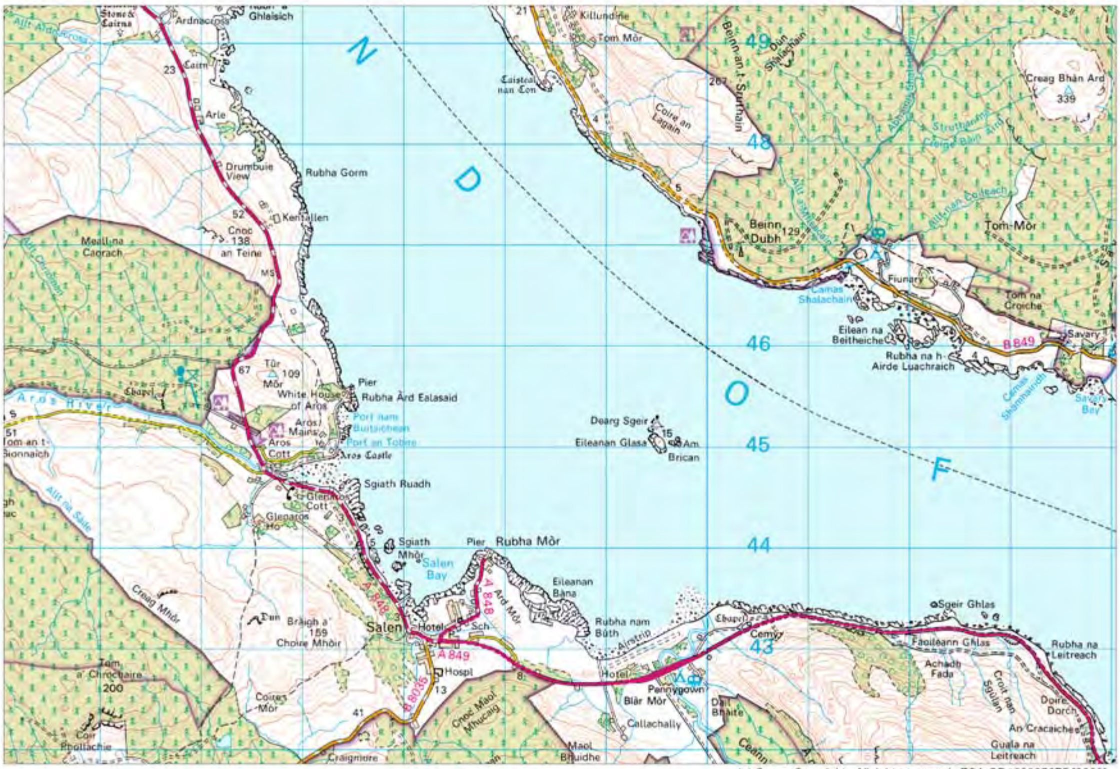

Figure 13.1 Sound of Mull: Aros

[redacted]

Figure 13.2 Bathymetry of Sound of Mull: Aros

The chart above shows that there is an intertidal area around the mouth of the Aros River extending southward around Salen Bay. This area is most pronounced at the mouth of the River Aros. Below MLWS, the depths drop off gradually toward the centre of the Sound of Mull A series of small islands and rocks extends outward into the sound from just south of Salen Bay, while the bay opens out to the Sound of Mull. Past these the sound reaches depths of over 100m in places. Depths within Salen Bay and just offshore of the fishery are less than 10m.

13.1 Tidal Curve and Description

The two tidal curves below are for Salen. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 GMT on 13/06/08 and the second is for seven days beginning 00.00 GMT on 20/06/08. 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.

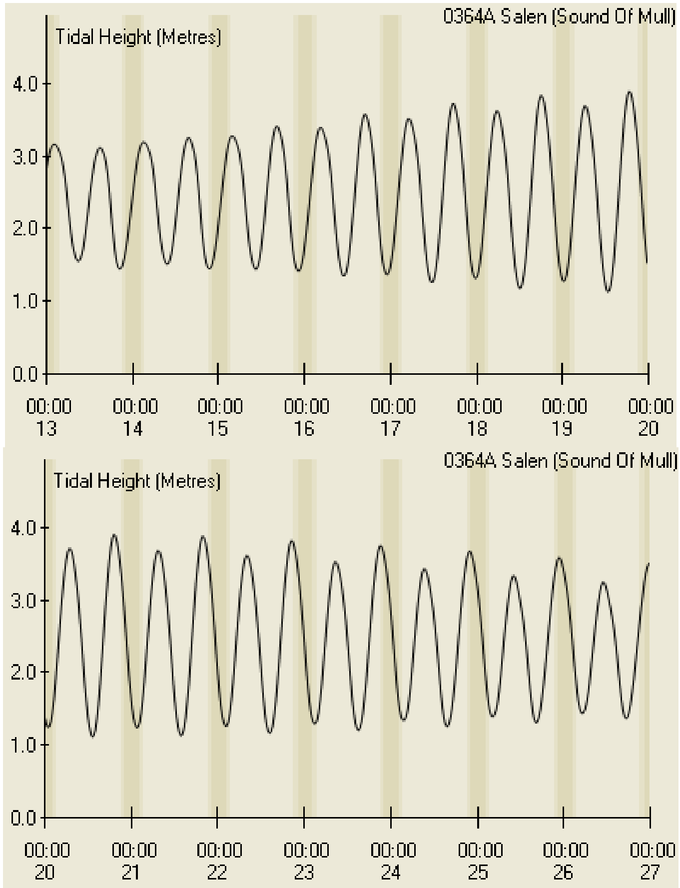

Figure 13.3 Tidal curves for Salen

The following is the summary description for Salen from TotalTide:
Salen (Sound Of Mull) is a Secondary Non-Harmonic port. The tide type is Semi-Diurnal. Predicted heights are in metres above Chart Datum.

MHWS	4.2 m
MHWN	3.1 m
MLWN	1.7 m
MLWS	0.7 m

The tidal range at spring tide is therefore approximately 3.5 m and at neap tide 1.4 m.

13.2 Currents

Currents in coastal waters 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.

Tidal stream information was available for one nearby location in the Sound of Mull, in the deeper water just to the north of the rocky islands in the middle of the sound. The tidal diamond (Table 13.1) indicates that tidally driven flows move in a north west direction on the flood tide, and a south east direction on the ebb tide. Tidal flow rates and directions at peak flow on a spring tide are illustrated in Figure 13.4. Flow rates were fairly slow, reaching a maximum of 0.4 m/s on a flooding tide, and 0.3 m/s on an ebbing tide. Therefore, flows along the shore in the Sound of Mull in the vicinity of production area are expected. Flows along the south shore of the sound here are likely to be slower than those experienced in the deeper water where the tidal diamond is located, and are likely to influenced by wind and complicated by interactions with headlands at either end of the bay.

Table 13.1 Tidal streams for SN037B (taken from TotalTide)

Time	Direction	Spring Rate (m/s)	Neap Rate (m/s)
-06h	000°	0.1	0.1
-05h	313°	0.3	0.1
-04h	309°	0.4	0.1
-03h	304°	0.4	0.1
-02h	300°	0.2	0.1
-01h		0.0	0.0
HW	101°	0.1	0.0
+01h	112°	0.2	0.1
+02h	132°	0.3	0.1
+03h	119°	0.3	0.1
+04h	133°	0.2	0.1
+05h	145°	0.2	0.1
+06h	066°	0.1	0.0

Figure 13.4. Tidal flows and direction at peak flow during a spring tide on the flood tide (top) and the ebb tide (bottom) at SN037B (taken from TotalTide)

Strong winds will create a surface current in the same direction as the wind. The bay is most exposed to the east, so winds from this direction are likely to affect circulation in the area the most. For some wind directions, the surface currents created may facilitate the movement of contamination from point sources towards the fishery, for example a south easterly wind may create currents which move contamination from the Salen septic tank outfall towards the shellfishery. Wind driven surface currents will create a return current, which may flow along the bottom or the sides of a water body depending on wind direction and local bathymetry. Onshore winds will increase wave action, which may resuspend contamination in the water.

Density (freshwater) driven flows are usually of greatest importance in enclosed estuaries and sea lochs which have considerable freshwater inputs. The area in which the fishery is located has an open aspect, but does have the Aros River entering it where the trestles are located. Therefore, when river discharge is high, localised reductions in salinity within the bay may be expected together with a net seaward flow of surface water, but as the bay has an open aspect it is expected that wind and tidally driven currents will be much more important.

13.3 Conclusions

The main point sources of contamination within the bay are the Salen septic tanks outfall, and the Aros River. The path of the Aros River flows directly over the trestles, so will most likely impact on the fishery irrespective of currents in the area. The Salen septic tank outfall is to the middle of Salen Bay approximately 1 km to the south east of the trestles in around 5 m of water. Contamination from this source will be carried in the approximate direction of the fishery on a flood tide. A south east wind would tend to create a surface current that may also carry contamination from here towards the fishery.

14. River Flow

There are no river gauging stations on rivers or burns along the Sound of Mull: Aros coastline. The largest watercourse entering the area was sampled and measured.

Table 14.1 River measurement and loading for Sound of Mull: Aros

No.	NGR	Description	Width (m)	Depth (m)	Flow (m/s)	Flow (m^3/day)	*E.coli* (cfu/ 100 ml)	Loading (*E. coli* per day)
1	NM 55655 44788	Aros River	13	0.34	0.176	67200	4500	3.0×10^{12}
2	NM 57193 43203	Stream	1.6	0.07	0.4	3871	1400	5.4×10^{10}

In addition to the above streams, a few smaller watercourses discharge to Sound of Mull: Aros, but these were either not accessible or not observed during the shoreline survey. All were much smaller than the Aros River and the stream at Salen. A land drain with flow insufficient to measure was found to be highly contaminated. As it was raining at the time of survey, it was not clear how much and under what conditions this water would normally flow.

The stream at Salen passes adjacent to the septic tank there, and a contractor was onsite when the area was surveyed. The bank of this stream where it passes by the septic tank was hardened with rock to approximately 1 m above the stream bed. The contractor reported that the stream, when in spate, significantly overtops its banks and reaches well up the side of the septic tank. At the time of survey, the stream was flowing well below this level despite the wet weather at the time. A water sample collected here contained 1400 E. coli / 100 ml, which is reasonably high. Though this stream is over 1 km away from the oyster trestles, it may add significantly to background levels of contamination throughout the bay.

The trestles are located in the path of the Aros River where it enters the bay. The river drains an area of forest and pasture, so the contamination it carries to the fishery is likely to mainly be of livestock origin. However, SEPA reported a consent for a domestic septic tank with a population equivalent of 10 to discharge to Aros River immediately upstream of where it enters production area and the positive norovirus results given in Appendix 9 would indicate an impact with human faecal material. At the time of survey, the river carried a bacterial loading of 3.0×10^{12} *E.coli* / day, a very similar one to that estimated for the Salen septic tank, the other major point source identified. Therefore, it can be concluded that the Aros River, by way of its loading and proximity to the trestles is the most important source of contamination to the fishery. Increased discharge from this river may result in increased levels of contamination within the oysters.

15. Shoreline Survey Overview

The sanitary survey at Sound of Mull: Aros was carried out in response to an application to harvest pacific oysters from the production area.

The shoreline survey was conducted on the 17th June 2008, with revisits for additional sample collections occurring on 3rd June, 5th August, and 19th August 2008.

There are currently 20 trestles with bagged oysters in place at Sound of Mull: Aros, at the mouth of Aros River. The harvester plans to add a further 10 trestles.

The location of the two communal septic tanks serving the settlement of Salen were confirmed. Both discharge to Sound of Mull: Aros. The larger of these was noted to be possibly susceptible to flooding from an adjacent stream. Some private septic tanks were noted in Salen, but none had outfalls to Sound of Mull: Aros. Another private septic tank serving one house was found in close proximity to the fishery. Human population in the area is likely to increase during the summer months, as Mull is a popular tourist destination. Hotels and B&Bs are present throughout the area. Boating activity in the immediate vicinity of the shellfishery is limited, but a few sailboats were observed passing offshore.

The land surrounding Sound of Mull: Aros is a primarily a mixture of pasture with some mixed woodland near the shore, with coniferous plantation and pasture further inland. Approximately 140 sheep were seen concentrated on a small area of pasture at Aros Bridge. A one day agricultural and livestock show is held in a field next to Aros Bridge in august every year. Geese were present in the area and though approximately 20-30 were observed the evening before the survey, only two were observed and counted during the survey walk itself. Oyster catchers and other wading birds were present but not in large concentrations. Several clusters of gulls numbering fewer than 20 birds were observed on the exposed seabed at low tide. No seals were observed during the survey, but they are reported to haul out on the sands near Aros.

Four seawater samples were taken during the course of the survey, yielding results ranging from 47 to 5100 *E. coli* cfu/100ml. The two samples giving lower results (both 47 *E. coli* cfu/100ml) had salinities of 34.0 and 34.3 ppt. Higher results of 5100 and 2200 *E. coli* cfu/100ml occurred in samples with a lower salinity (30.0 and 15.0 ppt respectively).

Two shore mussel samples were taken on the 17th June 2008 (the main survey date). The sample taken at Salen gave a result of 750 *E. coli* mpn/100g, and the sample taken near the mouth of Aros River gave a result of 20 *E. coli* mpn/100g. No oyster samples were taken on the 17th June 2008, as the trestles could not be accessed. Two oyster samples taken at either end of the trestles on the 3rd July gave results of 1300 and 1700 *E. coli* mpn/100g. Subsequent oyster samples taken on the 5th and 19th August gave results of 750 and 250 *E. coli* mpn/100g respectively.

A water sample from a stream flowing through Salen gave a result of 1400 *E. coli* cfu/100ml, while a sample taken from a drainage channel with minimal flow contained 16000 E. coli cfu/100ml. A water sample taken from Aros River, which discharges where the trestles were located gave a result of 4500 *E. coli* cfu/100ml.

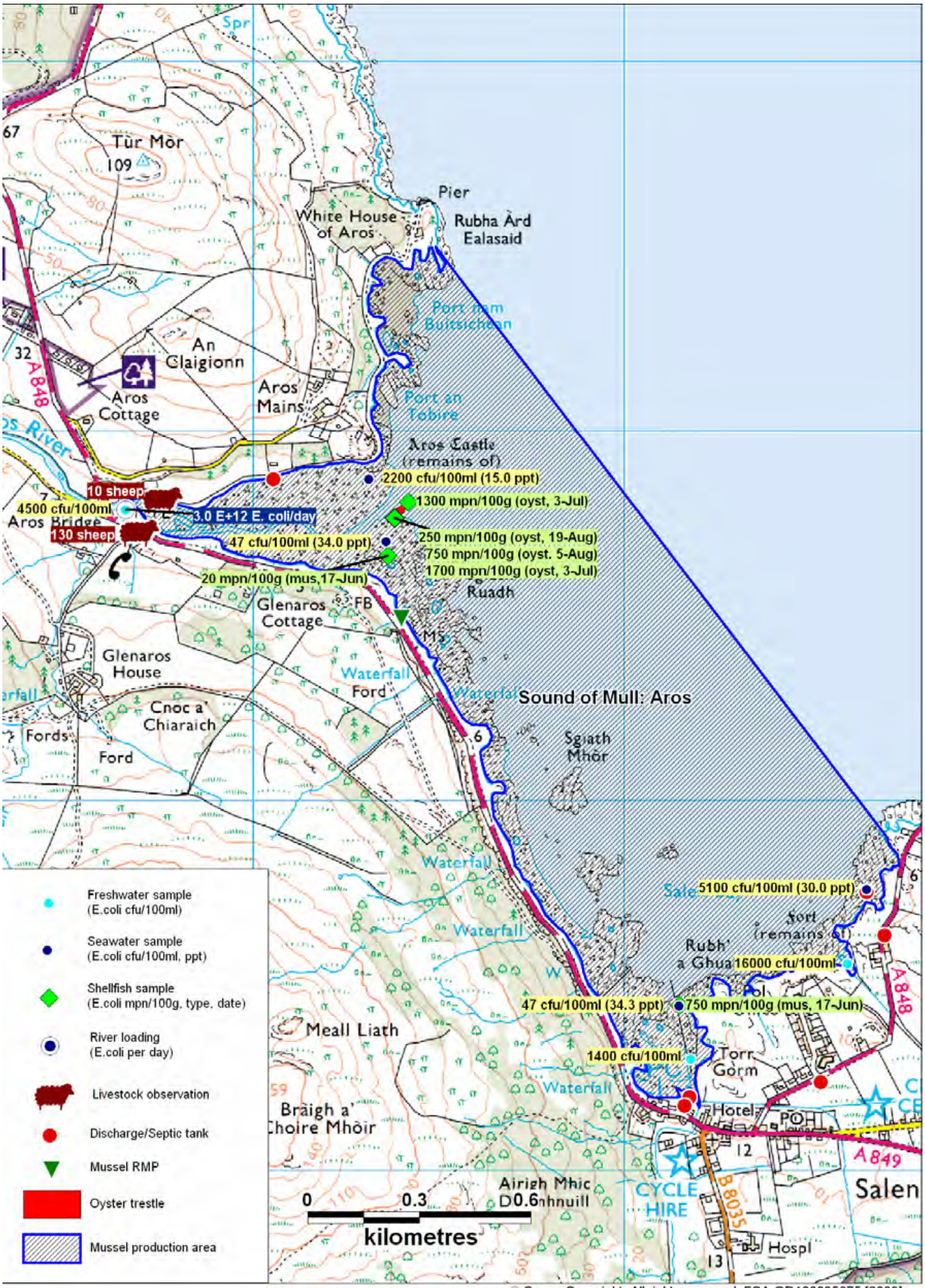

Figure 15.1 Summary of shoreline survey observations

16. Overall Assessment

Human sewage impacts

At the settlement of Salen, two communal septic tanks discharge to Sound of Mull: Aros. The largest of these (Salen ST) has a consented dry weather flow of 47 m^3/day, roughly equivalent to 250-300 people, giving a maximum estimated loading during dry weather of 3.4 x 10^{12} *E. coli* / day. The outfall is about 1 km to the south east of the oyster trestles and lies in about 5m of water. The extent to which this impacts the fishery will depend mainly on the pattern of water movement around the bay. The other communal septic tank (Ardmore Road) is much smaller, serving a population equivalent of 20 and discharges close to the low water mark at the south east end of Salen Bay.

SEPA lists 13 private discharge consents for septic tanks in the area, the majority of which discharge to soakaway. One has a partial soakaway on the shore just north of Sound of Mull: Aros, another discharges to an unnamed watercourse south of Salen, and another discharges to Allt Na Searmoin, which in turn discharges to the south end of Sound of Mull: Aros. Of greatest relevance to the fishery is a septic tank with a population equivalent of 10, which discharges to Aros River immediately upstream of where it enters Sound of Mull: Aros.

In addition to these, the shoreline survey identified that there were some private septic tanks at houses back from the shore at Salen and a further private discharge to the shore in close proximity to the fishery.

Boat traffic passing through the Sound of Mull may also give a minor contribution to levels of contamination in the area, although most would be expected to travel along the far side of the sound where the water is deeper.

Agricultural impacts

The land surrounding Sound of Mull: Aros is a mixture of forest and pasture. An important pathway for the transport of contamination from agricultural sources will be Aros River. Much of its catchment area is pasture, often steeply sloping. About 140 sheep were seen in fields adjacent to Aros River during the shoreline survey. These were the only livestock seen during the survey. Overall livestock densities in the two parishes bordering Sound of Mull: Aros were 44 sheep and 3.4 cattle per km^2 at the last census, but it must be noted that these densities are an average from an area of 672 km^2.

Numbers of livestock in the area may be expected to increase in spring, when lambs are born, and start to decrease in the autumn when they are sent for slaughter.

Wildlife impacts

Potential wildlife impacts to the fisheries at Sound of Mull: Aros include geese and other waterbirds, deer, seals and otters. Geese grazing on the pastures may constitute a source of diffuse contamination in the same manner as livestock, but their impacts will be minor relative to livestock, and less predictable as they are free to move around. Impacts from the other wildlife species are likely to be of less significance, and more localised and unpredictable. As a consequence, the presence of wildlife will not materially affect the sampling plans.

Seasonal variation

The Isle of Mull is a popular tourist destination which can be reached by a 45 minute ferry ride from Oban. Therefore, overall numbers of people on the Island will increase during the summer months. Hotels and B&Bs are present throughout the area.

Livestock numbers are likely to be higher in the summer, so inputs from livestock may be higher during the summer, particularly following high rainfall events. A one-day livestock show held in August annually near the Aros Bridge would provide a flush of faecal bacteria from the show ground to the river for some days following the show, though the duration of affect to the fishery would depend on the timing and amount of rainfall.

Weather is wetter and windier during the winter months, so more rainfall dependent contamination such as runoff from pasture and discharges from sewer overflows may be expected during these times.

Historic *E. coli* monitoring data for shore mussels at Sound of Mull: Aros showed seasonal differences, with mean results significantly higher in the summer compared to the winter. A weak positive relationship between *E. coli* results and water temperature was also found, and suggests that either inputs are higher in summer and/or the uptake of bacteria by mussels is higher in warmer water.

In conclusion, there is likely to be more contamination of both human and livestock origin during the summer months as the area is popular with tourists, and livestock numbers will be higher during summer, so levels of contamination in oysters will probably be higher in the summer, as was observed in mussels from the area.

Rivers and streams

The trestles are located just next to the path of the Aros River where it enters the bay. It drains an area of forest and pasture, so the contamination it carries to the fishery is likely to mainly be of livestock origin, although there is a SEPA consent for a domestic septic tank with a population equivalent of 10 to discharge to this watercourse just above the head of tide. Norovirus results indicate that faecal contamination is reaching the fishery. At the time of survey, the Aros River carried a bacterial loading of 3.0×10^{12} *E.coli* / day. Therefore, it can be concluded that the Aros River, by way of its loading and proximity to the trestles is likely to be an important source of contamination to the fishery. In addition a number of much smaller watercourses drain into the bay, but these are likely to be of very minor importance in comparison to the Aros River.

Meteorology, hydrology, and movement of contaminants

Currents in coastal waters are driven by a combination of tide, wind and freshwater inputs. Tidal stream information indicates that tidally driven flows in the Sound of

Mull near the fishery are relatively weak and move in a north west direction on the flood tide, and a south east direction on the ebb tide. Flows around the bay in which the production area is located are likely to be more complicated, but will still probably have a weak northwest flow on the flood tide. Given the lower current speeds, however, flows will be significantly affected by wind direction and strength. Contamination from the Salen Septic tank will be carried in the general direction of the oyster trestles on a flooding tide.

It was not appropriate to compare historic mussel *E. coli* sampling results with tidal state, as sampling was targeted at low water on spring tides.

However, a significant correlation between wind direction and historic *E. coli* results was found, with higher results occurring during periods of south easterly winds. This indicates that the river is not the only source of contamination to the fishery and generally coincides with the direction of the Salen septic tank discharge relative to the oyster trestles.

When historic mussel *E. coli* results were compared with recent rainfall, weak negative relationships were found. This is unexpected as higher rainfall generally results in more faecal contamination entering coastal waters via land runoff, and the Aros River enters the production area adjacent to the sampling sites. This may indicate that diffuse sources here are diluted with higher runoff levels associated with rainfall. However, no relationship was found between historic mussel *E. coli* results and salinity.

Temporal and geographical patterns of sampling results

No spatial pattern in historic mussel *E. coli* results could be clearly discerned because few results were reported at grid references other than the nominal RMP. All samples were taken from the intertidal zone around the mouth of the Aros River. No overall temporal trends were apparent in these results, which dated back to 2002. A seasonal effect was found, with results in the summer significantly higher than those in the winter.

Of the two shore mussel samples taken during the shoreline survey, a much higher level of contamination was found in the sample taken from near Salen than the one taken next to the mouth of Aros River. No major difference was seen in oyster sample results on the occasion when they were taken from either end of the area of trestles. Much greater variation was seen in the oyster sampling results between sampling dates. No obvious spatial pattern was observed in seawater sample results.

17. Recommendations

Firstly, it is recommended that monitoring and classification of the area for shore mussels be discontinued as there is no commercial fishery here requiring classification.

The recommended production area boundaries for Pacific oysters are the area bounded by lines drawn between NM 5642 4519 and NM 5667 4470 and between NM 5667 4470 and NM 5638 4455 and between NM 5600 4487 and NM 5600 4466 extending to MHWS.

To inform the location of the RMP, a number of factors should be taken into account including the actual location of the shellfish, any sampling results, and the likely most important sources of contamination. Water and shellfish sampling results from the shoreline survey do not provide robust evidence for the location of the RMP in any particular place within the area of trestles, which only cover a small area. The closest sources of contamination are the Aros River and private discharge on the shoreline just to the north of the river, so the RMP should be located as close to the path of this as possible.

Therefore, it is recommended that the RMP be set at NM 5638 4476 where a marked, dedicated sampling bag should be laid in order to ensure that sufficient stock are available for sampling from this point. Only stock of a harvestable size should be sampled. No sampling depth is applicable.

As this is a new species in this area, and seasonal fluctuations in *E. coli* results are expected, the sampling frequency should be monthly.

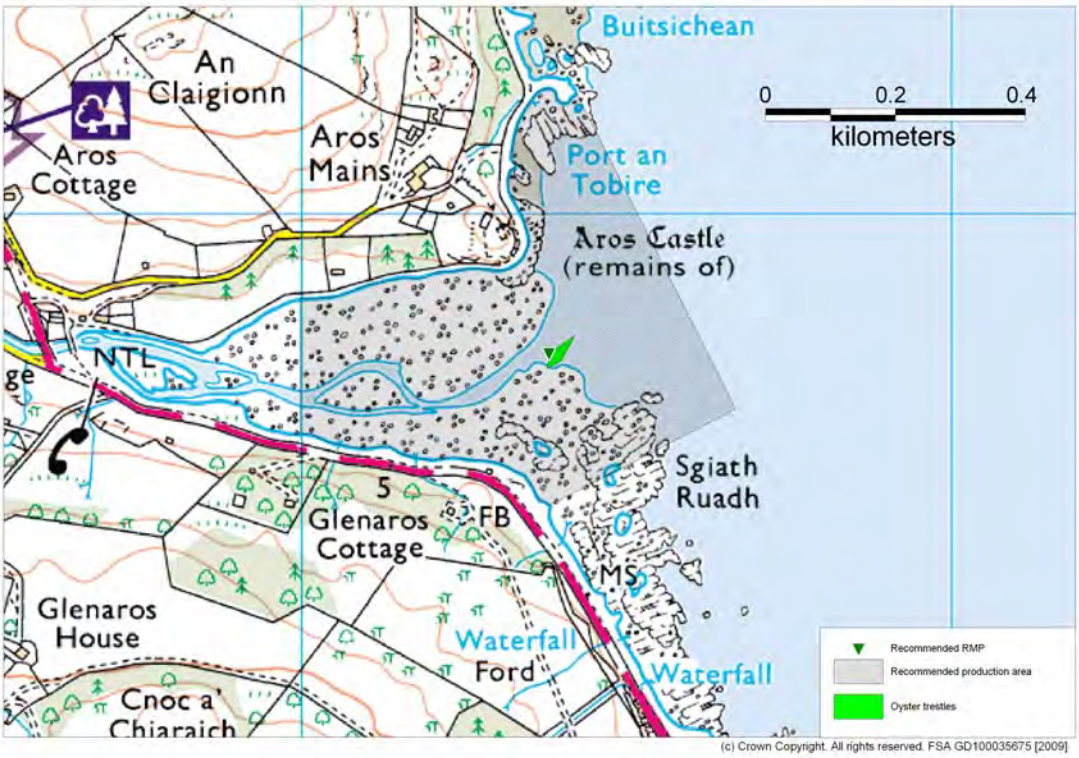

Figure 17.1. Recommended production area boundaries and RMP

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9. **Norovirus Testing Summary**

Sampling Plan for Sound of Mull: Aros (Pacific oysters)

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
Sound of Mull: Aros	Aros	AB 257 820	Pacific oyster	Trestle	NM 5638 4479	156380	744760	10	N/A	Hand	Monthly	Argyll & Bute Council	Christine McLachlan William MacQuarrie Ewan McDougall Donald Campbell	Christine McLachlan

Table of Proposed Boundaries and RMPs – Sound of Mull: Aros

Production Area	Species	SIN	Existing Boundary	Existing RMP	New Boundary	New RMP	Comments
Sound of Mull: Aros	Common mussel	AB 257 820 13	Area inshore of line drawn from NM 5651 4546 and NM 5769 4392	NM 564 445	None	None	No classified area recommended as no commercial mussel fishery exists here.
Sound of Mull: Aros	Pacific oyster	AB 257 820 13	Area inshore of line drawn from NM 5651 4546 and NM 5769 4392	N/A	Area bounded by lines drawn between NM 5642 4519 and NM 5667 4470 and between NM 5667 4470 and NM 5638 4455 and between NM 5600 4487 and NM 5600 4466 extending to MHWS	NM 5638 4476	The existing production area was curtailed to avoid areas further inshore along the Aros River and Salen Bay, where there were sewage discharges. New RMP.

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.

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

A variety of cetacean species are routinely observed around the west coast of Scotland.

Table 8.1 Cetacean sightings in 2007 – Western Scotland.

Common name	Scientific name	No. sighted*
Minke whale	*Balaenoptera acutorostrata*	28
Killer whale	*Orcinus orca*	183
Long finned pilot whale	*Globicephala melas*	14
Bottlenose dolphin	*Tursiops truncatus*	369
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. Source: Hebridean Whale and Dolphin Trust.

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 5km 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 per faecal deposit and ring-billedgulls (*Larus delawarensis*) approximately 1.77 x 10^8 FC per faecal deposit to a local reservoir (Alderisio and DeLuca, 1999). 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 and birds are known to carry *Salmonella*.

Deer

Deer are present throughout much of Scotland in significant numbers. The Deer Commission of Scotland (DCS) conducts counts and undertakes culls of deer in areas that have large deer populations.

Four species of deer are routinely recorded in Scotland, with Red deer (*Cervus elaphus*) being the most numerous, followed by Roe deer (*Capreolus capreolus*), Sika deer (*Cervus nippon*) and Fallow deer (*Dama dama*).

Accurate counts of populations are not available, though estimates of the total populations are >200,000 Roe deer, >350,000 Red deer, < 8,000 Fallow deer and an unknown number of Sika deer. Where Sika deer and Red deer populations overlap, the two species interbreed further complicating counts.

Deer will be present particularly in wooded areas where the habitat is best suited for them. Deer, like cattle and other ruminants, shed *E. coli*, *Salmonella* and other potentially pathogenic bacteria via their faeces.

Other

The European Otter (*Lutra lutra*) is present around Scotland with some areas hosting populations of international significance. Coastal otters tend to be more active during the day, feeding on bottom-dwelling fish and crustaceans among the seaweed found on rocky inshore areas. An otter will occupy a home range extending along 4-5km of coastline, though these ranges may sometimes overlap (Scottish 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.

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

One-way ANOVA of Log *E. coli* result by season with Tukeys comparison

```
Source   DF      SS     MS     F      P
season    3   4.174  1.391  3.14  0.033
Error    51  22.565  0.442
Total    54  26.740

S = 0.6652   R-Sq = 15.61%   R-Sq(adj) = 10.65%


                           Individual 95% CIs For Mean Based on Pooled StDev
Level   N    Mean   StDev   -+---------+---------+---------+--------
1      13  2.4355  0.7617               (--------*--------)
2      15  2.8272  0.7291                         (--------*-------)
3      18  2.2950  0.5886             (------*-------)
4       9  2.0246  0.5328   (-----------*----------)
                            -+---------+---------+---------+--------
                           1.60      2.00      2.40      2.80

Pooled StDev = 0.6652


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

Individual confidence level = 98.95%


season = 1 subtracted from:

season    Lower   Center   Upper  ---------+---------+---------+---------+
2       -0.2784   0.3917  1.0619                 (-------*-------)
3       -0.7842  -0.1405  0.5032          (-------*-------)
4       -1.1778  -0.4109  0.3560     (---------*--------)
                                  ---------+---------+---------+---------+
                                        -0.80      0.00      0.80      1.60


season = 2 subtracted from:

season    Lower   Center    Upper  ---------+---------+---------+---------+
3       -1.1505  -0.5322   0.0860       (------*-------)
4       -1.5483  -0.8026  -0.0570  (--------*--------)
                                   ---------+---------+---------+---------+
                                         -0.80      0.00      0.80      1.60


season = 3 subtracted from:

season    Lower   Center   Upper  ---------+---------+---------+---------+
4       -0.9924  -0.2704  0.4516        (--------*--------)
                                  ---------+---------+---------+---------+
                                        -0.80      0.00      0.80      1.60
```

Regression Analysis: Log *E. coli* result versus 2 day rain

```
The regression equation is
logres for rain = 2.57 - 0.0121 2 day rain


Predictor        Coef   SE Coef      T      P
Constant       2.5704    0.1240  20.73  0.000
2 day rain  -0.012118  0.006777  -1.79  0.081


S = 0.694230   R-Sq = 6.8%   R-Sq(adj) = 4.7%
```

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	1.5409	1.5409	3.20	0.081
Residual Error	44	21.2060	0.4820		
Total	45	22.7469			

Unusual Observations

Obs	2 day rain	logres for rain	Fit	SE Fit	Residual	St Resid
4	14.5	1.000	2.395	0.106	-1.395	-2.03R
11	86.5	1.602	1.522	0.526	0.080	0.18 X
42	0.1	4.204	2.569	0.124	1.635	2.39R

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

One-way ANOVA of Log *E. coli* result by 2 day rainfall quartile with Tukeys comparison

Source	DF	SS	MS	F	P
2drq	3	4.202	1.401	3.17	0.034
Error	42	18.545	0.442		
Total	45	22.747			

S = 0.6645   R-Sq = 18.47%   R-Sq(adj) = 12.65%

```
                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  ---------+---------+---------+---------+
Q1     11  2.9035  0.5897                    (-------*-------)
Q2     16  2.4676  0.6720             (-----*------)
Q3      9  2.0180  0.7281  (--------*--------)
Q4     10  2.2897  0.6711        (--------*-------)
                           ---------+---------+---------+---------+
                                  2.00      2.50      3.00      3.50
```

Pooled StDev = 0.6645

Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of 2drq

Individual confidence level = 98.93%

2drq = Q1 subtracted from:

```
2drq    Lower   Center    Upper    -+---------+---------+---------+--------
Q2    -1.1315  -0.4359   0.2598           (--------*-------)
Q3    -1.6837  -0.8854  -0.0872    (---------*---------)
Q4    -1.3898  -0.6137   0.1623        (--------*---------)
                                   -+---------+---------+---------+--------
                                 -1.60     -0.80     -0.00      0.80
```

2drq = Q2 subtracted from:

```
2drq    Lower   Center   Upper    -+---------+---------+---------+--------
Q3    -1.1896  -0.4496  0.2905          (--------*---------)
Q4    -0.8938  -0.1779  0.5381              (--------*--------)
                                  -+---------+---------+---------+--------
                                -1.60     -0.80     -0.00      0.80
```

```
2drq = Q3 subtracted from:

2drq    Lower  Center   Upper    -+---------+---------+---------+--------
Q4    -0.5444  0.2717  1.0877               (---------*----------)
                                 -+---------+---------+---------+--------
                               -1.60     -0.80     -0.00      0.80
```

Regression Analysis: Log *E. coli* result versus 7 day rain

```
The regression equation is
logres for rain = 2.83 - 0.0110 7 day rain


Predictor        Coef   SE Coef      T      P
Constant       2.8318    0.1451  19.51  0.000
7 day rain  -0.011039  0.003162  -3.49  0.001


S = 0.636262   R-Sq = 21.7%   R-Sq(adj) = 19.9%


Analysis of Variance

Source          DF       SS      MS      F      P
Regression       1   4.9345  4.9345  12.19  0.001
Residual Error  44  17.8125  0.4048
Total           45  22.7469


Unusual Observations

     7 day    logres
Obs   rain  for rain     Fit  SE Fit  Residual  St Resid
 11    110    1.6021  1.6175  0.2550   -0.0155     -0.03 X
 28     92    3.1139  1.8162  0.2031    1.2977      2.15R
 29    109    1.3010  1.6286  0.2520   -0.3275     -0.56 X
 42      0    4.2041  2.8318  0.1451    1.3723      2.22R

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

One-way ANOVA of Log *E. coli* result by 7 day rainfall quartile with Tukeys comparison

```
Source  DF      SS     MS     F      P
7drq     3   5.658  1.886  4.64  0.007
Error   42  17.089  0.407
Total   45  22.747

S = 0.6379   R-Sq = 24.87%   R-Sq(adj) = 19.51%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  ----+---------+---------+---------+-----
Q1     13  2.7054  0.7541                      (------*------)
Q2     13  2.5417  0.6279                   (------*------)
Q3     11  2.5961  0.4778                   (-------*-------)
Q4      9  1.7455  0.6375  (--------*-------)
                           ----+---------+---------+---------+-----
                             1.50      2.00      2.50      3.00

Pooled StDev = 0.6379


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of 7drq

Individual confidence level = 98.93%
```

```
7drq = Q1 subtracted from:

7drq    Lower   Center    Upper  -------+---------+---------+---------+--
Q2    -0.8324  -0.1637   0.5050           (-----*------)
Q3    -0.8078  -0.1093   0.5892           (------*------)
Q4    -1.6992  -0.9599  -0.2206  (------*-------)
                                 -------+---------+---------+---------+--
                                     -1.0       0.0       1.0       2.0


7drq = Q2 subtracted from:

7drq    Lower   Center    Upper  -------+---------+---------+---------+--
Q3    -0.6441   0.0544   0.7529             (------*------)
Q4    -1.5355  -0.7962  -0.0569    (------*------)
                                 -------+---------+---------+---------+--
                                     -1.0       0.0       1.0       2.0


7drq = Q3 subtracted from:

7drq    Lower   Center    Upper  -------+---------+---------+---------+--
Q4    -1.6169  -0.8506  -0.0843   (------*-------)
                                 -------+---------+---------+---------+--
                                     -1.0       0.0       1.0       2.0
```

Regression Analysis: Log *E. coli* result versus water temperature

```
The regression equation is
logresult for temp = 1.51 + 0.0730 WaterTemp


Predictor     Coef  SE Coef     T      P
Constant    1.5122   0.2730  5.54  0.000
WaterTemp  0.07300  0.02076  3.52  0.001


S = 0.650016   R-Sq = 19.8%   R-Sq(adj) = 18.2%


Analysis of Variance

Source          DF       SS      MS      F      P
Regression       1   5.2239  5.2239  12.36  0.001
Residual Error  50  21.1261  0.4225
Total           51  26.3500


Unusual Observations

                logresult
Obs  WaterTemp   for temp     Fit  SE Fit  Residual  St Resid
  4       18.0     1.0000  2.8261  0.1469   -1.8261     -2.88R
 15       30.0     2.6990  3.7021  0.3761   -1.0031     -1.89 X
 48       19.0     4.2041  2.8991  0.1638    1.3050      2.07R

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

Circular-Linear correlation of log *E. coli* results by wind direction

CIRCULAR-LINEAR CORRELATION
Analysis begun: 22 October 2008 14:28:07

Variables (& observations)	r	p
Angles & Linear (42)	0.32	0.018

Regression Analysis: Log *E. coli* result versus salinity

```
The regression equation is
logresult for salinity = 2.28 + 0.0102 Salinity


Predictor      Coef  SE Coef      T      P
Constant     2.2784   0.2165  10.52  0.000
Salinity    0.01024  0.01281   0.80  0.428


S = 0.725515   R-Sq = 1.4%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.3362  0.3362  0.64  0.428
Residual Error  46  24.2131  0.5264
Total           47  24.5493


Unusual Observations

               logresult
                     for
Obs  Salinity   salinity    Fit  SE Fit  Residual  St Resid
 46       0.0      4.204  2.278   0.217     1.926     2.78R

R denotes an observation with a large standardized residual.
```

Hydrographic Methods

1.0 Introduction

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. This document collects together information common to all hydrographic assessments avoiding the repetition of information in each individual report.

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

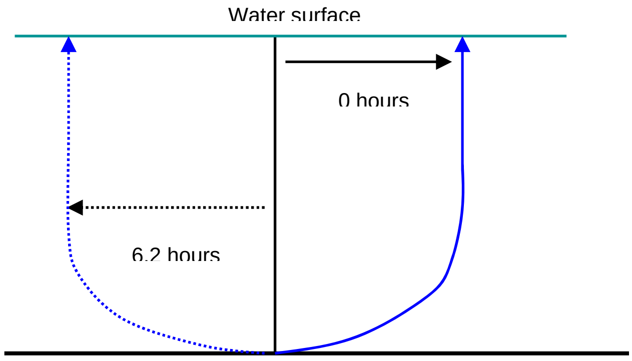
The regulations require an appreciation of the hydrography and currents within a region classified for shellfish production.

2.0 Background processes

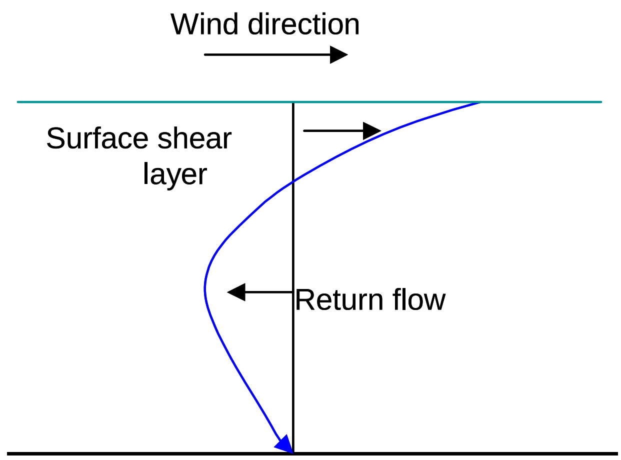
This section gives an overview of the hydrographic processes relevant to sanitary surveys.

Movement in the estuarine and coastal waters is generally driven by one of three mechanisms: 1) Tides, 2) Winds, 3) Density differences. Unless tidal flows are weak they usually dominate over the short term (~12 hours) and move material over the length of the tidal excursion. The tidal residual flow acts over longer time scales to give a net direction of transport. Whilst tidal flows generally move material in more or less the same direction at all depths, wind and density driven flows often move material in different directions at the surface and at the bed. Typical vertical profiles are depicted in figure 1. However, it should be understood that in a given water body, movement will often be the sum of all three processes.

a)



b)



c)

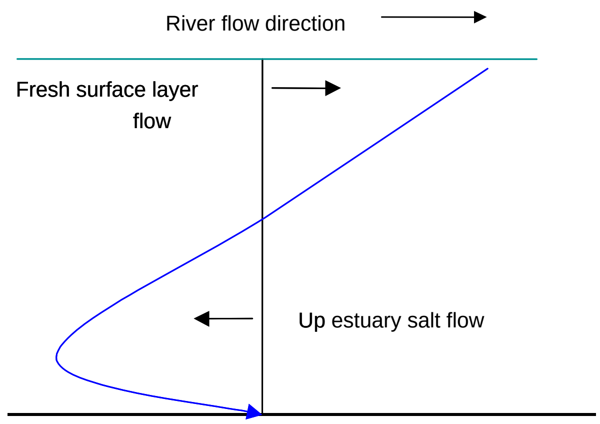


Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

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.

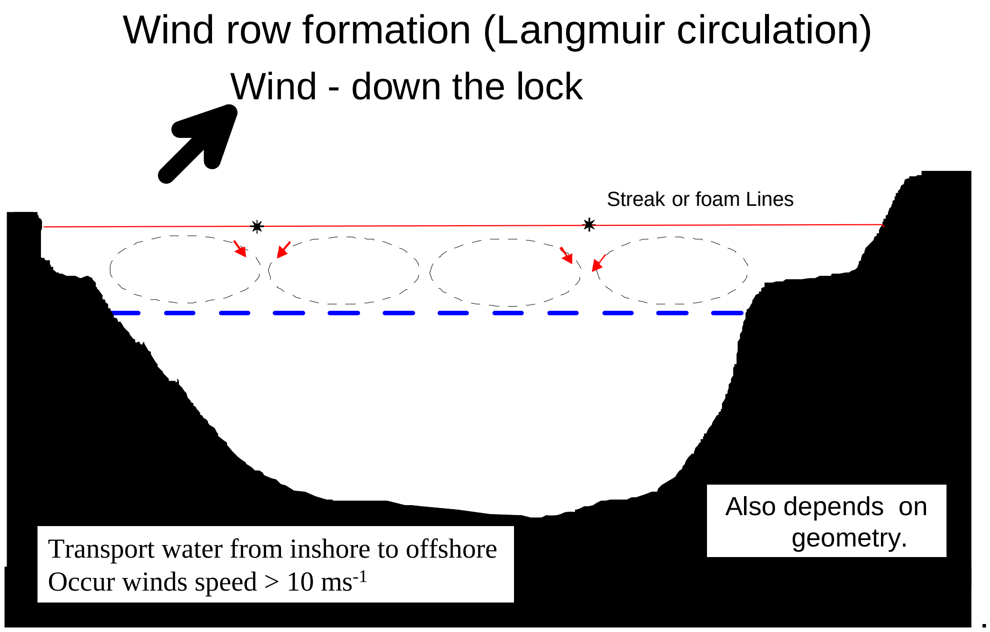


Figure 2: Schematic of wind driven ‘wind row’ currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Shoreline Survey Report

Sound of Mull: Aros
AB 257

Scottish Sanitary Survey Project

Cefas

Shoreline Survey Report

Prod. area: Sound of Mull: Aros
Site name: Aros Oysters
Species: Pacific Oysters
Harvester:
Local Authority: Argyll & Bute Council
Status: New Site

Date Surveyed: 17 June 08
Surveyed by: Michelle Price-Hayward, Christine McLachlan
Existing RMP: Not yet established
Area Surveyed: See Map in Figure 1

Weather observations:
Windy and rainy. Little significant rain 3 weeks prior to survey. Air temperature 10°C. Wind ?, force 3-4.

Fishery

The oyster farm at Aros is located near the mouth of the Aros River. The harvester currently has 20 trestles down at the site with plans to add approximately 10 more. On the day of survey, it was not possible to obtain an oyster sample as the low pressure and wind resulted in the low tide being higher than predicted and the trestles were not uncovered.

The trestles are accessible only during low water at spring tides.

A further visit was undertaken by Christine McLachlan from Argyll & Bute Council to record the boundaries of the fishery and collect oyster samples. The boundaries of the oyster farm are illustrated in Figure 1.

Sewage/Faecal Sources

Two septic tanks were observed at Salen. One was located off the A848 past a new development of private homes. This did not have any signage. The homes to the southwest of this are were reported to be on private septic tanks. Further to the southwest, nearer the centre of town was the Salen Waste Treatment works, also a septic tank. There was a public convenience adjacent. The outfall from the tank discharges into Salen Bay. The stream had a cut bank above, which reportedly helped to contain the flow when the stream was flooding. This reached near the top of the septic tank. One other private discharge pipe was observed during the survey, however it was not known whether it was discharging.

Sheep were observed in fields near the Aros river and in fields near the shoreline.

Seasonal Population

There is likely to be a significantly higher impact due to tourism in the summer as the Isle of Mull is a popular destination. Hotels and B&Bs are present throughout the area.

Boats/Shipping

Sailboats were observed passing between Mull and the mainland throughout the day. While no specific observation of numbers was made, it would be reasonable to say at least 1-2 every hour.

Land Use

The nearest settlement is Salen, which is located along the main road north from the ferry pier. There is coniferous plantation in the area, along with some grazing. A one-day agricultural and livestock show is held during August each year in a field adjacent the Aros Bridge.

Wildlife/Birds

Geese were present in the area and though roughly 20-30 were observed the evening before the survey, only two were observed and counted during the survey walk. Goose droppings were present on the shoreline, indicating their presence in the area. Oystercatchers and other wading birds were present but not in large concentrations. Several clusters of gulls numbering fewer than 20 birds were observed on the exposed seabed at low tide.

No seals were observed during the shoreline survey, though they are reported to haulout on the sands near Aros.

Figure 1. Map of Shoreline Observations

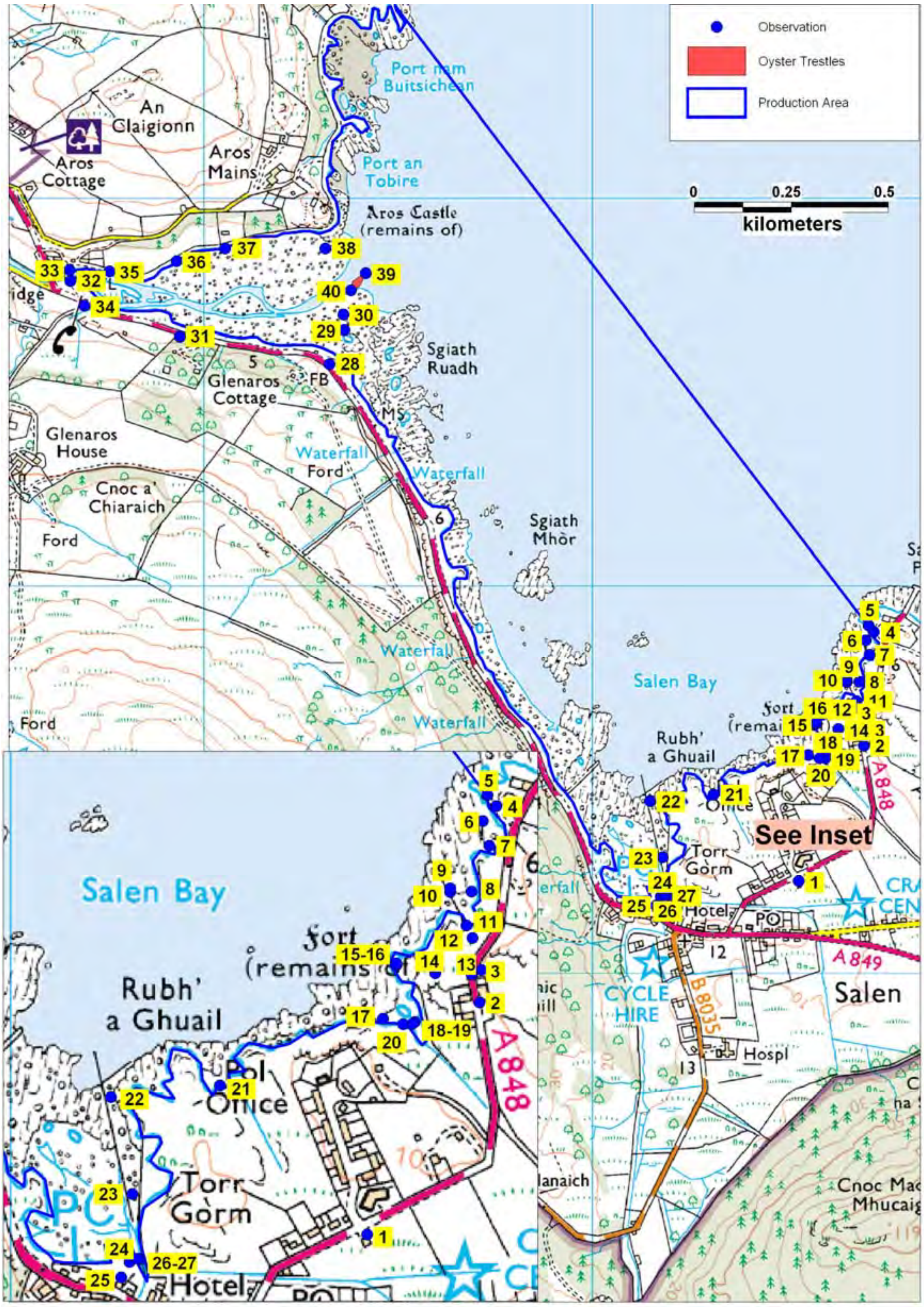


Table 1. Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Description
1	17/06/2008	9:17	NM 57532 43240	157532	743240		Processing plant. Houses with private septic tanks
2	17/06/2008	9:28	NM 57700 43588	157700	743588		Houses end here
3	17/06/2008	9:30	NM 57703 43636	157703	743636	Figure 5	Possible septic tank, no signage
4	17/06/2008	9:36	NM 57725 43882	157725	743882		Remains of wood pier. 2 houses, possibly 4. Other 2 look like red sheds.
5	17/06/2008	9:40	NM 57712 43899	157712	743899	Figures 6-8	Photographs looking at pier, 180^0 from pier, and 90^o from pier
6	17/06/2008	9:43	NM 57705 43860	157705	743860		Rocky shore, bottom - rock scree cover, softer underlay of mud - worm casts occasional. Few inverts, no shore mussels. Land - scrub, grass above trees.
7	17/06/2008	9:46	NM 57715 43823	157715	743823		Pottery shards
8	17/06/2008	9:53	NM 57688 43754	157688	743754	Figure 9	Seaweed, looks like toilet paper
9	17/06/2008	9:56	NM 57656 43753	157656	743753	Figure 10	Septic tank outfall
10	17/06/2008	10:00	NM 57656 43759	157656	743759		Water sample 1, salinity 30 ppt.
11	17/06/2008	10:05	NM 57681 43703	157681	743703	Figures 11-12	Black PVC pipe adjacent to iron septic tank - not actively discharging. 110mm internal diameter, open both ends
12	17/06/2008	10:11	NM 57690 43684	157690	743684		Boggy area, ragged robin, ladies bedstraw, cotton grass, orchids
13	17/06/2008	10:16	NM 57688 43629	157688	743629	Figure 13	Iron manhole cover, possible septic tank
14	17/06/2008	10:19	NM 57634 43631	157634	743631		Curlew. No animal droppings on shore.
15	17/06/2008	10:21	NM 57576 43644	157576	743644		Small animal trap (set without bait)
16	17/06/2008	10:23	NM 57576 43646	157576	743646	Figure 14	Droppings with a high grass content, possibly from a goose. 3-4 per metre in this area.
17	17/06/2008	10:40	NM 57556 43564	157556	743564		Mud worm casts
18	17/06/2008	10:42	NM 57603 43559	157603	743559		No specific observation
19	17/06/2008	10:42	NM 57600 43556	157600	743556		Goose droppings
20	17/06/2008	10:43	NM 57586 43555	157586	743555		More shells (scallops, cockles, limpets)
21	17/06/2008	10:54	NM 57312 43463	157312	743463	Figure 15	Small field drain, not flowing much. Water Sample 2. Washed up creels. Rough grassland.
22	17/06/2008	11:06	NM 57149 43446	157149	743446	Figure 17	Outfall pipe, at least 7 concrete pipe casing sections, with 5m between each. Salinity 10ppt at shore. Water sample 3, shore mussel 1

No.	Date	Time	NGR	East	North	Associated photograph	Description
23	17/06/2008	11:22	NM 57181 43301	157181	743301	Figures 18-20	Septic tank next to stream. Water sample 4. Photographs (1 upstream, 1 downstream & 1 of bank above septic tank)
24	17/06/2008	11:29	NM 57177 43199	157177	743199	Figure 21	Corner of septic tank works
25	17/06/2008	11:30	NM 57164 43176	157164	743176	Figure 22	Other corner of Salen WWTW works. Public convenience adjacent.
26	17/06/2008	11:54	NM 57193 43203	157193	743203		Stream 1.03m wide, 0.7 m deep, flow 0.4m/s (water sample taken no.23)
27	17/06/2008	12:00	NM 57189 43204	157189	743204		Corrogated pipe
28	17/06/2008	12:37	NM 56322 44574	156322	744574		Shoreline adjacent to oysters
29	17/06/2008	12:42	NM 56361 44662	156361	744662		Shore mussel sample
30	17/06/2008	12:53	NM 56358 44702	156358	744702		Water sample 5, salinity 35ppt
31	17/06/2008	13:05	NM 55937 44645	155937	744645		Gated entrance to field
32	17/06/2008	13:24	NM 55655 44788	155655	744788	Figure 23	Aros river. 34cm deep, 13m wide, flow 0.176m/s. Water sample Aros 6
33	17/06/2008	13:38	NM 55652 44817	155652	744817		3 large houses
34	17/06/2008	13:46	NM 55691 44724	155691	744724		130 sheep in field may be more out of view up field
35	17/06/2008	13:52	NM 55755 44813	155755	744813		Field with 10 sheep
36	17/06/2008	13:55	NM 55928 44839	155928	744839		Field with 1 horse
37	17/06/2008	13:58	NM 56054 44872	156054	744872		House with discharge pipe. Looks lived in, possibly a holiday house. Sign marking cables.
38	17/06/2008	14:07	NM 56312 44872	156312	744872		Seawater sample Aros 7, salinity 15ppt
39	03/07/2008	-	NM 56416 44808	156416	744808		Oyster sample 1, Seawater sample 1
40	03/07/2008	-	NM 56378 44764	156378	744764		Oyster sample 2
42	06/08/2008	-	NM 56381 44764	156381	744764	Figure 24-25	Oyster sample 3
43	21/08/2008	-	NM 56379 44764	156379	744764		Oyster sample 4

Photographs referenced in the table can be found as Figures 5-25.

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.

Sampling

Water and shellfish samples were collected at sites marked on the map. Samples were transferred to cool boxes for transport to the laboratory. All samples were analysed for *E. coli* content. Water sampled at the site was tested for salinity using a hand held refractometer. These readings are recorded in Table 1 as salinity in parts per thousand (ppt).

Samples were also tested for salinity by the laboratory using a salinity meter under more controlled conditions. These results are more precise than the field measurements and are shown in Table 2, given in units of grams salt per litre of water. This is the same as ppt.

Bacteriology results follow in Tables 2 and 3.

Table 2. Water Sample Results

Date	No.	Sample	Grid Ref	Type	E. coli (cfu/100ml)	chloride mg c/l
17/06/08	1	Aros 1	NM 57656 43759	Seawater	5100	16500
17/06/08	2	Aros 2	NM 57603 43559	Freshwater	16000	
17/06/08	3	Aros 3	NM 57149 43446	Seawater	47	18900
17/06/08	4	Aros 4	NM 57181 43301	Freshwater	1400	
17/06/08	5	Aros 5	NM 56358 44702	Seawater	47	18700
17/06/08	6	Aros 6	NM 55655 44788	Freshwater	4500	
17/06/08	7	Aros 7	NM 56312 44872	Seawater	2200	8270
03/07/08	8	Seawater sample 1	NM 73431 35569	Seawater	540	2200

Table 3. Shellfish Sample Results

Date	No.	Sample	Grid Ref	Type	E. coli (cfu/100g)
17/06/08	1	Aros Mussel 1	NM 57149 43446	Shore Mussel	750
17/06/08	2	Aros Mussel 2	NM 56361 44662	Shore Mussel	20
03/07/08	3	Oyster sample 1	NM 56416 44808	Oyster	1300
03/07/08	4	Oyster sample 2	NM 56378 44764	Oyster	1700
05/08/08	5	Oyster sample 3	NM 56381 44764	Oyster	750
19/08/08	6	Oyster sample 4	NM 56379 44764	Oyster	250

Figure 3. Water sample results map

Figure 4. Shellfish sample results map

Photographs

Figure 5. Septic tank

Figure 6. Old pier

Figure 7. Homes back from shore near old pier

Figure 8. House on shoreline adjacent old pier

Figure 9. Algae on shoreline

Figure 10. Septic tank outfall

Figure 11. Black discharge pipe

Figure 12. Iron septic pipe, not discharging

Figure 13. Septic tank cover

Figure 14. Goose faeces found on shoreline

Figure 15. Creels on shoreline

Figure 16. Allt na Searmoin near Sale

Figure 17. Outfall

Figure 18. Stream from shore

Figure 19. Stream adjacent Salen works

Figure 20. View of upper bank of stream, fence around treatment works at top.

Figure 21. Corner of Salen Treatment works

Figure 22. Salen Treatment Works

Figure 23. Aros river.

Figure 24. Oyster trestles at Aros

Figure 25. Oyster trestles at Aros, looking toward the northwest.

Norovirus Testing Summary

Sound of Mull: Aros

Oyster samples taken from the oyster trestle at Sound of Mull: Aros were submitted for Norovirus analysis quarterly between May 2008 and February 2009. Results are summarised in the table below.

Ref No.	Date rec'd	NGR	GI	GII
08/147	04/07/2008	NM 56378 44764	Positive	Positive
08/194	15/10/2008	NM 56378 44761	Positive at LOD	Not Detected
09/003	15/01/2009	NM 56379 44763	Positive	Positive
09/061	28/04/2009	NM 56381 44761	Positive	Positive at LOD