Scottish Sanitary Survey Programme

Sanitary Survey Report

Production Area: Loch Moidart

SIN: HL 179 227 13

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Cefas

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Buidheann Inbhe-Bìdhe

Report Distribution – Loch Moidart

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Appendices

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I. Executive Summary

Loch Moidart was identified for sanitary survey as a replacement for the survey originally scheduled for a new oyster farm at Camas an Lighe, and for which the application was withdrawn by the harvester.

Loch Moidart is located on the west coast of Scotland, on the north side of the Ardnamurchan peninsula. The loch is split into two channels; the North and South Channels. The shellfish farm is located in the South Channel. The two channels are divided by the island of Eilean Shona. The population density is low for the areas surrounding the Loch Moidart fishery. There are several dwellings nearby but most of these are in seasonal occupation. The small settlement of Newton of Ardtoe is 1.5 km inland to the south east.

The Loch Moidart fishery consists of Pacific oysters (*Crassostrea gigas*) grown in triangular bags suspended from ropes set at approximately one metre above the seabed and at or just below MLWS. Rafts are to be put in place in the near future, from which the triangular bags will be suspended. Harvesting may occur at any time of year.

Sewage discharges at the mouth of Faodhail Dhub and at Newton of Ardtoe are likely to have a significant impact on the fishery at Loch Moidart. Possible intermittent discharges from boats near the fishery may also be a contributing factor. Contamination originating in the River Shiel will contribute to background levels in the water and will have limited impact at the fishery depending on circulation and currents in Loch Moidart.

It is likely that a significant proportion of any faecal contamination reaching the fishery is from diffuse, livestock sources. Livestock numbers within the area surrounding the fishery are relatively high, particularly for sheep, with numbers of sheep being highest in the summer. Livestock had access to the shoreline and direct deposition of droppings at the shoreline and in and around watercourses is likely to pose the greatest threat to water quality at the fishery. There is also the potential for direct runoff from the hillside to the south east of the fishery to carry livestock faeces to the waters immediately east of the shellfish farm.

Overall, the wildlife species most likely to be present in or around Loch Moidart are likely to be present in modest numbers and will contribute to background levels of contamination at the fishery. Seabirds are most likely to be present during the summer months and gulls and cormorants may rest on the ropes throughout the year. Other wildlife species present in the surrounding area include seals, deer and otters.

Significant seasonal variation was observed in rainfall, with higher rainfall generally occurring during the autumn and winter. It is therefore expected that run off levels carrying diffuse pollution will be greatest in the autumn and winter although significant rainfall events during summer may have a higher

impact on the fishery, due to the first flush effect of accumulated livestock droppings being washed to the fishery via watercourses.

There are several watercourses in the area, and of those sampled three had high results indicating faecal contamination. Two of these were relatively close to the fishery (<1km) and the contamination is likely to impact on the shellfish there. The channel where the fishery is located is relatively shallow and thus any contaminants arising there will be subject to limited dilution. The bags of oysters located towards the shore will be impacted more by contamination arising from more local sources. Due to water movements in the wider Loch Moidart, the bags of oysters on the northern side of the farm will be exposed to contamination arising from further afield for a longer period than those towards the shore. If rafts are used in the future, the oysters will be further from sources of contamination at the adjacent shore but will be exposed to that from other sources on a continuous basis, with the impact depending on location of source and the direction of the current. The nature and extent of any contamination will depend on the location of the rafts. However, the main sources of contamination lie to the east and southeast of the existing oyster farm and therefore it is anticipated that this part of the fishery will be most affected.

Recommendations

Production area

Based on recorded sources of faecal contamination, it is recommended that the production area boundaries be curtailed to exclude the upper Foadhail Dhubh and areas nearer the River Sheil. The recommended boundaries are therefore the area bounded by lines drawn between NM 6490 7268 and NM 6494 7200 and between NM 6458 7179 and NM 6439 7179 and between NM 6347 7253 and NM 6338 7334 and extending to MHWS.

RMP

It is recommended that the RMP be relocated to NM 6439 7197, which lies nearer to sources to the east and southeast of the oyster farm.

Further information on recommendations relating to sampling depth, tolerance and frequency can be found in the sampling plan overleaf and in Section 17 of the report.

II. Sampling Plan

PRODUCTION AREA	Loch Moidart
SITE NAME	South Channel
SIN	HL 179 227 13
SPECIES	Pacific oysters
TYPE OF FISHERY	Aquaculture
NGR OF RMP	NM 6439 7197
EAST	164390
NORTH	771970
TOLERANCE (M)	20
DEPTH (M)	Not applicable
METHOD OF SAMPLING	Hand
FREQUENCY OF SAMPLING	Monthly
LOCAL AUTHORITY	Highland Council Lochaber
AUTHORISED SAMPLER(S)	Stephen Lewis
LOCAL AUTHORITY LIAISON OFFICER	Alan Yates

III. Report

1. General Description

Loch Moidart is located on the west coast of Scotland, north of the Island of Mull. The loch is split into two channels, North and South, divided by the island of Eilean Shona. There is a classified production area in the South Channel for Pacific oysters. The South Channel is oriented roughly east to west, and is open to seas from the west. Two rivers, the Moidart and the Shiel, discharge to the waters of the loch to the east of the South Channel. The River Shiel connects the Loch Moidart with the freshwater Loch Shiel.

Loch Moidart was identified for sanitary survey as a replacement for the survey originally scheduled for a new oyster farm at Camas an Lighe, and for which the application was withdrawn by the harvester.

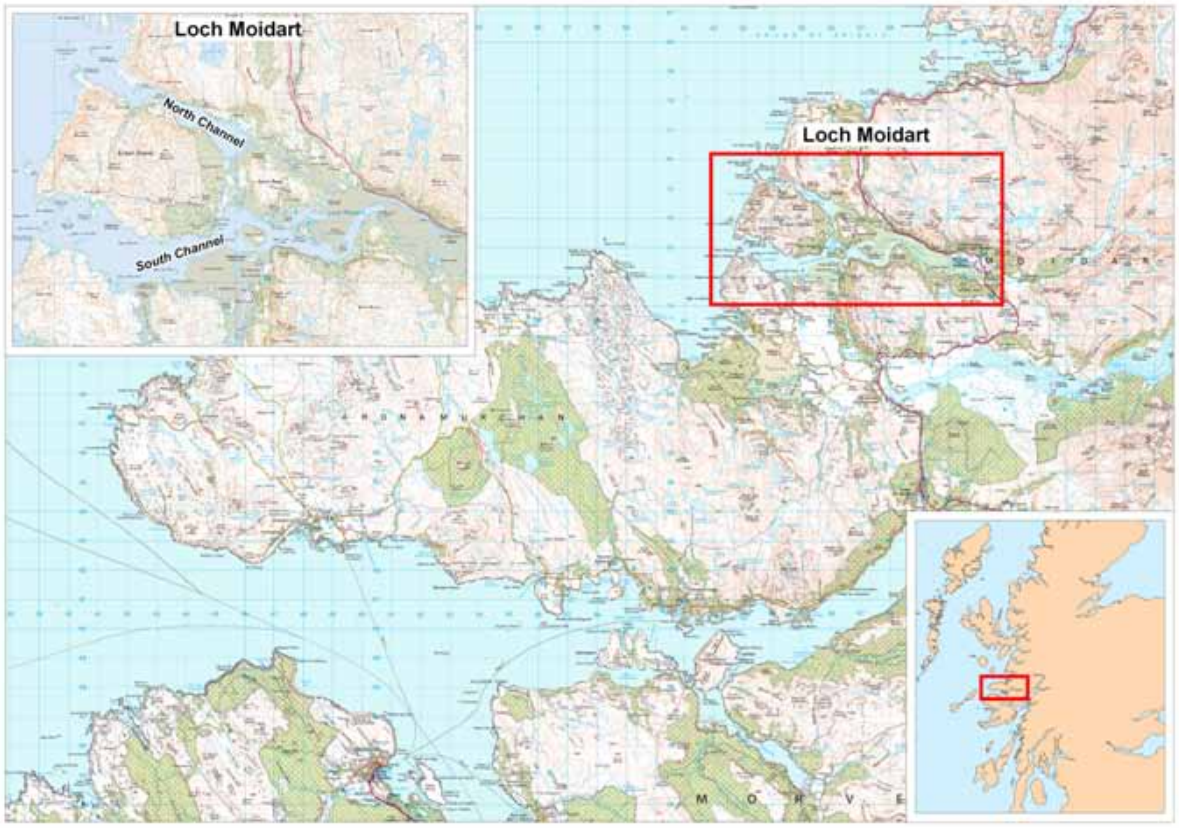

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Figure 1.1 Location of Loch Moidart

2. Fishery

The fishery at Loch Moidart consists of a single farmed site at the north end of Faodhail Dhubh on which Pacific oysters (*Crassostrea gigas*) are grown in triangular bags suspended from ropes set at approximately one metre above the seabed and at or just below MLWS. A dedicated line is set in place for sampling purposes that holds two baskets of oysters. This is set higher up the shore and is accessible at any spring tide. During the shoreline survey there was little to no stock available on the lines, as the harvester was in the process of clearing out to move production offshore. Rafts are to be put in place in the near future, from which the triangular bags will be suspended. Harvesting may occur at any time of year.

The current production area boundary is defined by lines drawn between NM 6271 7347 and NM 6279 7270 and between NM 6500 7274 and NM 6500 7188. The nominal Representative Monitoring Point (RMP) is reported at NM 6427 7189, which is reported to lie 50 m south of the shellfish farm.

The actual location of the oyster farm within the loch was recorded during the shoreline survey and is shown together with the production area boundaries, seabed lease, RMP and lease areas, in Figure 2.1.

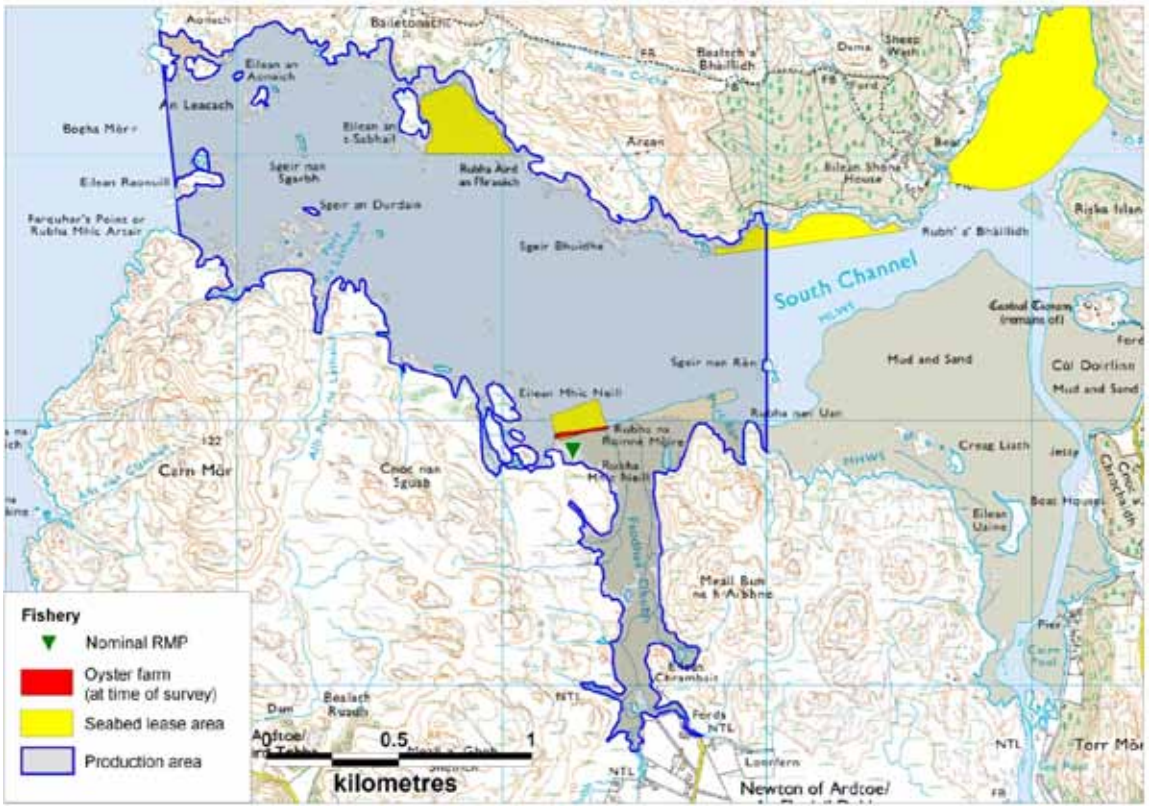

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Figure 2.1 Loch Moidart: South Channel Fishery

3. Human Population

Information on the human population of the area around Loch Moidart was obtained from the General Register Office for Scotland. Data was provided for the 2001 census by output area. The population density for the output areas nearest the fishery is shown thematically mapped in Figure 3.1.

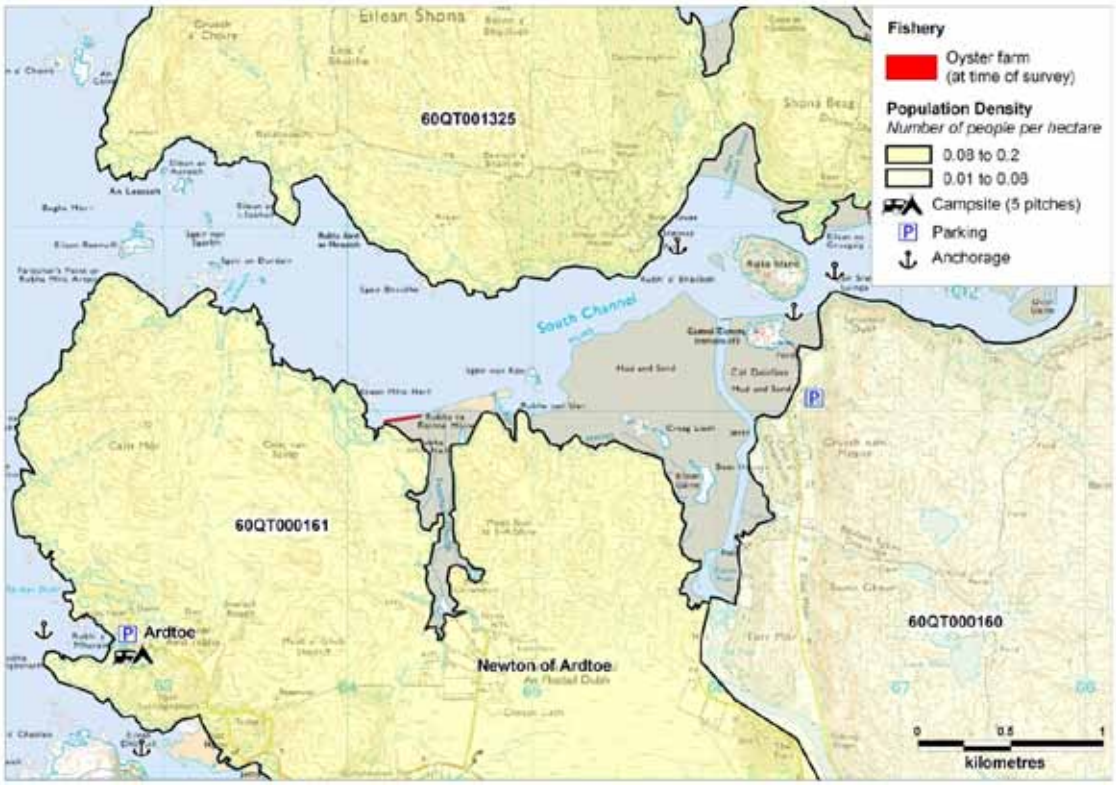

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Figure 3.1 Population map of Loch Moidart

Population density is low for the areas surrounding Loch Moidart. There is no access to the shorelines adjacent to the fishery and the nearest track ends 1.5 km inland to the south east at the small settlement of Newton of Ardtoe. There are several dwellings located along the track, although it was noted during the shoreline survey that majority of these are in seasonal occupation. Ardtoe has parking and a small caravan/campsite with 5 pitches. The village of Acharacle is located on the River Shiel, 5.5 km south east of the fishery. There are two hotels and other guest accommodation at Acharacle, as well as a primary school and medical centre.

The population for each census area in the surrounding area is listed in Table 3.1.

Table 3.1 Census output areas: Loch Moidart

Output area	Population
60QT000160	77
60QT000161	126
60QT001325	78
Total	**281**

There are three anchorages located east of the fishery and a fourth is located west of Ardtoe (Clyde Cruising Club, 2005). During the shoreline survey there were small workboats present on moorings around the area, and one yacht on a mooring just offshore of the oyster farm.

4. Sewage Discharges

Information on sewage discharges in the vicinity of the fishery was sought from Scottish Water and the Scottish Environment Protection Agency (SEPA). Scottish Water community sewage discharge assets identified for the area surrounding Loch Moidart are listed in Table 4.1.

Table 4.1 Discharges identified by Scottish Water

No.	Consent Ref No.	NGR of discharge	Discharge Name	Discharge Type	Level of Treatment	Consented flow m^3/day	Consented Design PE
1	-	NM 6765 6889	Acharacle WWTW	continuous	secondary	max 200	840
2	-	NM 6743 6891	Acharacle SPS 1	intermittent	EO/CSO	-	-
3	-	NM 6765 6888	Acharacle SPS 2	intermittent	EO/CSO	-	-
4	-	NM 679 678	Acharacle SPS 3	intermittent	EO/CSO	-	-
5	-	NM 680 683	Acharacle SPS 4	intermittent	EO/CSO	-	-

- data not provided
EO emergency overflow CSO combined sewer overflow SPS sewage pumping station

Sanitary data was provided for this discharge. Suspended solids and BOD (biochemical oxygen demand) results from 14 sampling occasions between June 2009 and March 2012 were provided. All values reported were within limits prescribed by the Urban Waste Water Treatment Directive. No microbiological data was available for this discharge.

According to Scottish Water, 129 properties are connected to the works at Acharacle, and this constitutes the majority of properties in the village. Based on an average PE per property of 2.11 persons/property (the SW design basis), the PE in current use is 272. The consented design PE provides capacity for tourist loading during the summer months and for future population growth.

Information relating to consented sewage discharges to the area was provided by SEPA and these consents are listed in Table 4.2.

Table 4.2 Discharge consents identified by SEPA

No	Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Consented/ design PE	Discharges to
1	CAR/R/1077541	NM 67770 73910	Sewage	Septic tank	7	Soakaway
2	CAR/R/1077526	NM 67880 73687	Sewage	Septic tank	7	Soakaway
3	CAR/R/1022308	NM 66130 70360	Sewage	Septic tank	7	Land
4	CAR/R/1039210	NM 65958 70481	Sewage	Septic tank	5	U/T* of River Shiel
5	CAR/R/1077219	NM 65894 70491	Sewage	Septic tank	6	Soakaway
6	CAR/R/1040793	NM 65870 70500	Sewage	Septic tank	5	Soakaway

*U/T: unnamed tributary

There were relatively few discharge consents identified in the vicinity of the fishery. There has been no historical requirement to register septic tanks in Scotland, therefore there are likely to be additional sanitary systems not identified in Table 4.1. No consent information was received for Eilean Shona House, which operates as holiday accommodation for up to 16 guests plus two staff who live in house. Further dwellings are situated along the banks of

the River Shiel. Acharacle was outwith the request area for discharges, consequently no consent was received for this discharge from SEPA. The Shellfish Growing Waters Report identified the Acharacle Wastewater Treatment Works as being a significant source of sewage to the River Shiel. (http://apps.sepa.org.uk/shellfish/pdf/83.pdf, accessed 02/05/12). However, the report also identified that upgrade of the Acharacle public sewage treatment facilities are not included in the improvement plan for the growing waters, and that the SGW is expected to pass the guideline standard in 2015.

Discharge pipes, tanks, and observations related to potential sewage sources recorded during the shoreline survey are listed in Table 4.3.

Table 4.3 Discharges and septic tanks observed during shoreline surveys

No.	Date	NGR	Description
1	05/07/2011	NM 66143 71138	Septic tank, 2 houses. Tideline comes right up to the tank, a larger spring tide would inundate the tank. Water sample 3 (seawater)
2	05/07/2011	NM 66121 70933	House, small septic tank, holiday let.
3	05/07/2011	NM 66209 71326	Pipe offshore roughly 30 m from road, at least 1 metre deep, not flowing, possibly running from house.
4	05/07/2011	NM 64707 70814	Septic tank outfall from holiday cottage, dry. Corrugated plastic pipe 30 cm diameter, Tank in garden above
5	05/07/2011	NM 64742 70795	Caravan on adjacent property, inspection port at property line suggests both properties on same tank. Small discharge pipe below caravan, Green corrugated plastic, 10 cm diameter,
6	05/07/2011	NM 64822 70790	Septic tank next to caravan. No obvious outlet. Stagnant stream with red bacterial film.
7	06/07/2011	NM 67526 68819	Acharacle WWTW.
8	06/07/2011	NM 67436 68967	End of a drainage pipe, no flow apparent at time
9	06/07/2011	NM 64632 71775	Cabin, gutter drain appears to join toilet drain from under cabin, pipe runs to a septic tank approx. 30 m away. No one in cabin – harvester at work on site.
10	06/07/2011	NM 64617 71789	Septic pipe, dribbling lightly

There are several small discharges from houses in the locality of Loch Moidart. SEPA discharges identified as 1 and 2 in Table 4.1 are located several kilometres to the north-east of the fishery in Loch Moidart (see Figure 4.1). The remaining consents identified by SEPA relate to discharges located on the western shores of the River Shiel. All but one of these pertains to small discharges to soakaway or land. If appropriately situated and maintained, these should not significantly impact water quality at the fishery. One discharge was to an unnamed tributary of the River Shiel, very close to the river itself. This would contribute to the total faecal load carried by the river, which would be expected to contribute to contamination levels found at the oyster farm.

During the shoreline survey a small number of homes were observed at Newton of Ardtoe, approximately 1.5 km south of the fishery. The majority were holiday lets with only two homes in permanent occupation. These homes were not served by mains sewerage. Three septic tanks and two discharge pipes were found, none of which was actively flowing at the time of survey. A freshwater sample was taken in the vicinity which gave an elevated result of 7400 *E. coli*/100 ml, suggesting significant faecal contamination of the water. However, it was not possible to determine what proportion of this was due to human versus other sources.

A cabin was observed on the eastern shore of Faodhail Dhubh relatively close to the oyster farm. The cabin, which belongs to the harvester, is reported to only be used on an occasional basis. This had a septic tank and a discharge pipe was observed just above the shoreline, presumably from this septic tank (observations 9 and 10 in Table 4.2). The roof guttering appeared to be connected into a water pipe leading to the septic tank, which would lead to larger and more frequent discharges from the tank.

During the shoreline survey a small number of properties were observed along the east shore of the River Shiel, many of which are in seasonal occupation. One septic tank was observed on the eastern shore of the river which appeared to serve two houses (discharge observation 1). A seawater sample was taken in this location which gave high result of 2900 *E. coli*/100 ml, indicating faecal content. This tank lies very near to the high tide line, and is likely to contribute faecal contamination to the tidal part of the river, especially when inundated on unusually high tides.

Small workboats were present during the shoreline survey on moorings around the fishery, and one yacht was present on a mooring just offshore of the oyster farm. Any overboard discharge of septic waste in the vicinity of the fishery would be expected to significantly impact water quality there.

Conclusions

Sewage discharges at the mouth of Faodhail Dhubh and at Newton of Ardtoe are likely to have the most impact on the fishery at Loch Moidart. Possible intermittent discharges from boats near the fishery may also be a contributing factor. Contamination originating in the River Shiel will contribute to background levels in the water and will have the impact at the fishery will depend on circulation and currents within Loch Moidart.

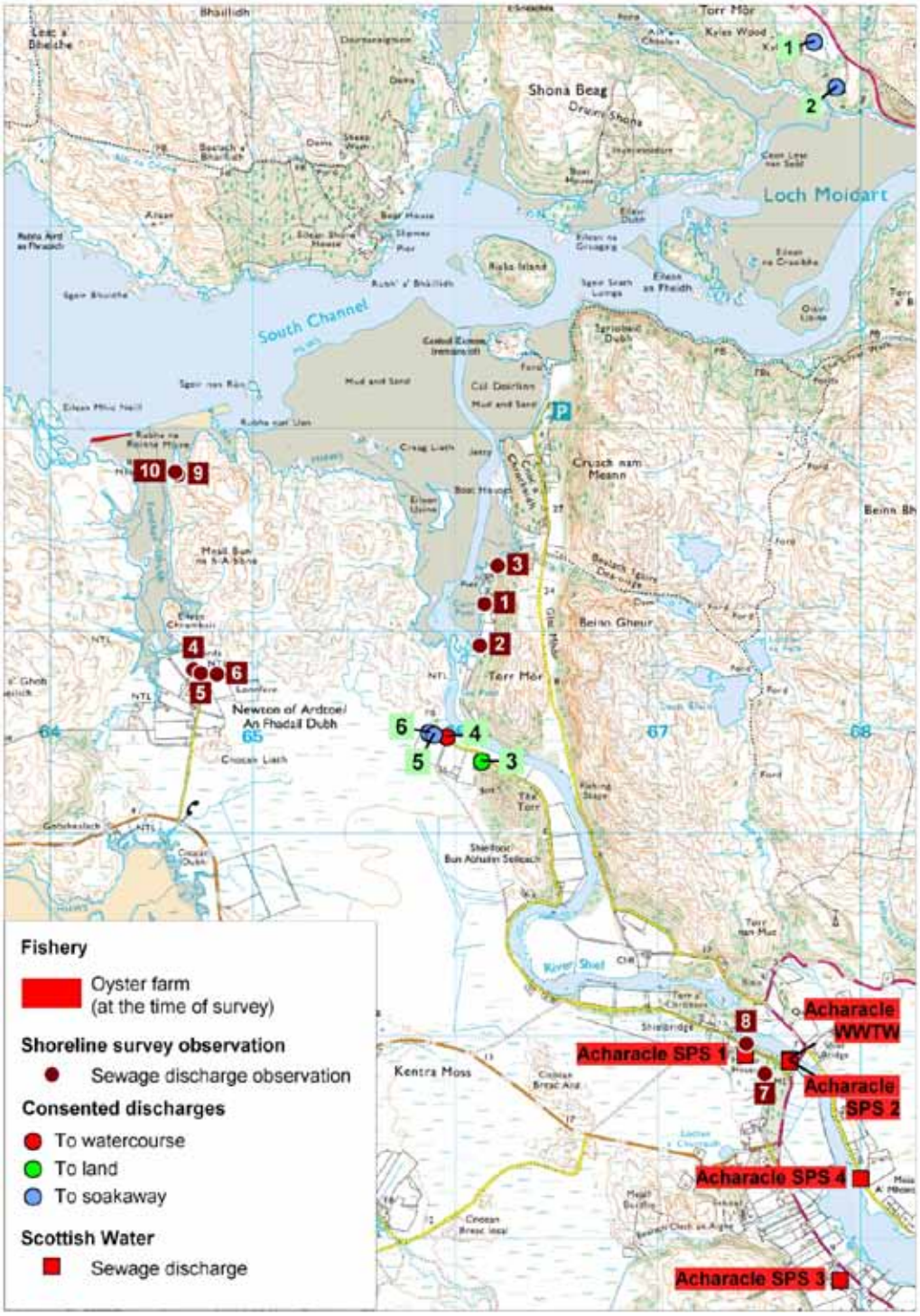

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Figure 4.1 Map of discharges for Loch Moidart

5. Geology and Soils

Geology and soil types were assessed following the method described in Appendix 2. A map of the resulting soil drainage classes is shown in Figure 5.1. Areas shaded red indicate poorly draining soils while areas shaded blue indicate more freely draining soils.

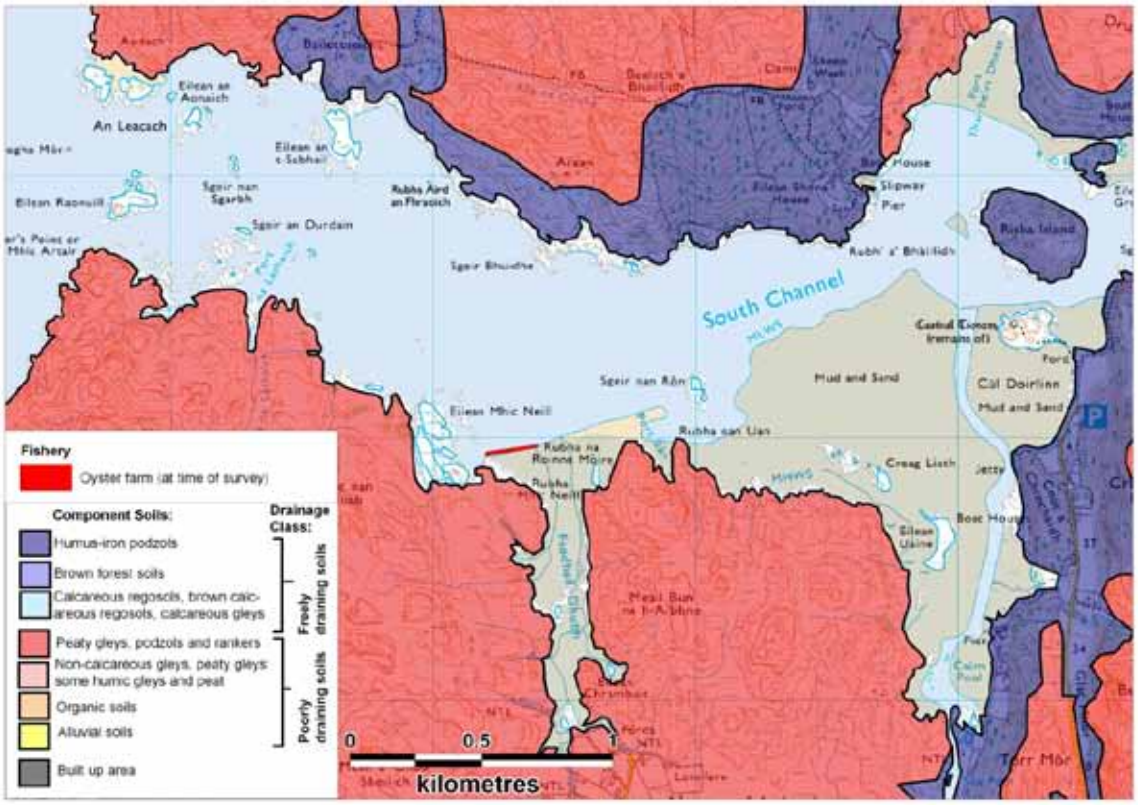

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Figure 5.1 Component soils and drainage classes for Loch Moidart

The predominant type of component soil present in this area is classed as poorly draining. It is composed primarily of peaty gleys, podzols and rankers. This soil type covers the land south of the fishery, additional areas along the northern coastline and inland areas to the east and the north.

Small, scattered areas of more freely-draining soils are found around the South Channel, most predominantly along the eastern shoreline and the northern shoreline opposite the fishery. There are no built up areas near to the fishery.

The potential for runoff contaminated with *E. coli* from human and/or animal waste is high along the immediate coastline around the Loch Moidart fishery, and low along the south shore of Eilean Shona, to the north, and along the east side of the mouth of the River Shiel. Septic tanks identified in Section 4 that discharge to land or soakaway along the west bank of the River Shiel are located on an area of poorly drained soil, therefore increasing the risk of contamination to the River Sheil if they are not properly maintained.

Properties presumed to be on soakaway systems at Newton of Ardtoe are similarly located in an area identified as poorly draining and so would pose an increased risk of contamination to Faodhail Dhubh if not maintained.

6. Land Cover

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

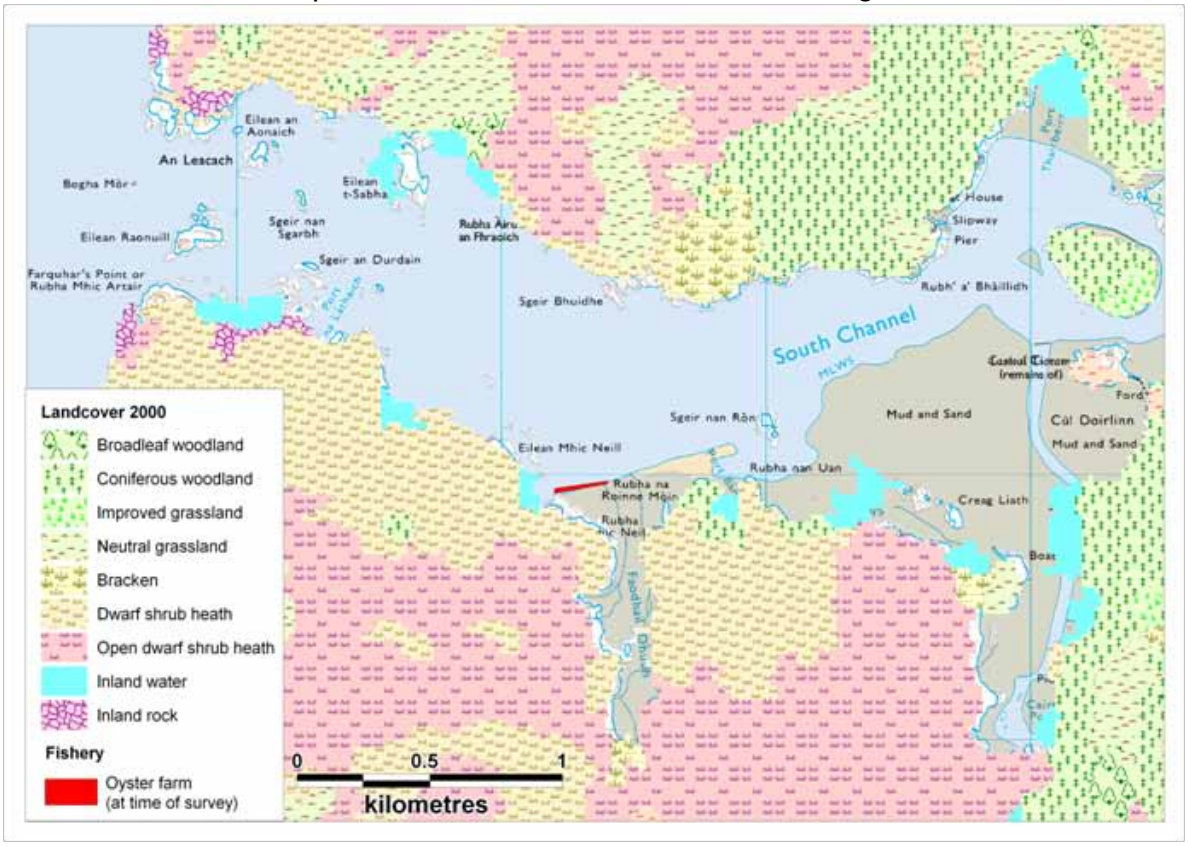

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Figure 6.1 LCM2000 class land cover data for Loch Moidart

The majority of land around the south channel of Loch Moidart is covered in heath. Extensive areas of coniferous woodland are found along the eastern shore of Eilean Shona and along the east bank of the River Shiel. Improved grassland is found in very small patches, including the southeast side of Riska Island at the east end of the channel. There is no improved grassland adjacent to the fishery and no areas classed as built up or urban. Areas of heath and grassland of all types may used for rough grazing.

An area of improved grassland around observed during the shoreline survey around farms at the head of Faodhail Dhubh is not identified in the land cover data.

Faecal indicator organism export coefficients for faecal coliform bacteria have been found to be approximately $8.3x10^{8}$ cfu km^{-2} hr^{-1} for areas of improved grassland and approximately $2.5x10^{8}$ cfu km^{-2} hr^{-1} for rough grazing (Kay et al. 2008). Lowest contributions would be expected from areas of woodland (approximately $2.0x10^{7}$ cfu km^{-2} hr^{-1}) (Kay *et al*. 2008). The contributions from all land cover types would be expected to increase significantly after

rainfall events, however this effect would be particularly marked from improved grassland areas (roughly 1000-fold) (Kay et al. 2008).

The highest risk of contamination attributable to landcover type is from the improved grassland areas at the head of Faodhail Dhubh. Runoff from this area would contribute contamination directly to the fishery, and would be expected to have a much greater impact after heavy rainfall. The potential for contamination from the remaining area is moderate to low, depending on the extent of land used for rough grazing.

7. Farm Animals

Information on the spatial distribution of animals on land adjacent to or near the fishery can provide an indication of the potential amount of organic pollution from livestock entering the shellfish production area. Agricultural census data to parish level was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for the Ardnamuchan and Arasaig & Moidart parishes. Reported livestock populations for the parishes in 2009 and 2010 are listed in Table 7.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reporting would have made it possible to discern individual farm data. Any entries which relate to less than five holdings, or where two or fewer holdings account for 85% or more of the information, are replaced with an asterisk.

Table 7.1 Livestock numbers in the Ardnamurchan and Arasaig and Moidart parish 2009 - 2010

	Ardnamurchan 457 km^2				**Arasaig & Moidart** 466 km^2			
	2009		2010		2009		2010	
	Holdings	Numbers	Holdings	Numbers	Holdings	Numbers	Holdings	Numbers
Pigs	*	*	8	34	*	*	*	*
Poultry	23	347	28	428	15	4180	19	4346
Cattle	30	835	32	848	24	749	23	746
Sheep	50	10034	48	10618	21	2581	22	2826
Other horses and ponies	9	19	9	21	10	28	11	32

Combined, both agricultural parishes cover the entire Ardnamurchan and Moidart districts and both encompass similar sized areas. Whilst both parishes have similar numbers of cattle, the Ardnamurchan parish has almost five times as many sheep numbers compared to the Arasaig and Moidart parish. Large numbers of sheep are kept within the parish, with much smaller numbers of cattle and other livestock. However, it is the number of animals kept within the catchment and near shore of the fishery that will be most likely to affect water quality there.

The only significant source of spatially relevant information was the shoreline survey (see Appendix 6), which only relates to the time of the site visit on the 5th and 6th July 2011. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1.

Twelve cattle were seen grazing on fields at a farm at Newton of Ardtoe, where there was a shed for winter housing with a muck spreader parked outside. Presumably this would be used to transport faecal wastes from livestock housing to on-farm storage or spreading on land. However, this is reportedly left parked near to one of the streams discharging to Faodhail Dhubh, where faecal waste is washed into the stream with rainfall. Sheep

droppings were observed in the strand line and on the intertidal shore south of the fishery, particularly along the eastern shore of Faodhail Dhubh. Small numbers of chickens were seen along the River Shiel, but no large poultry operations.

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

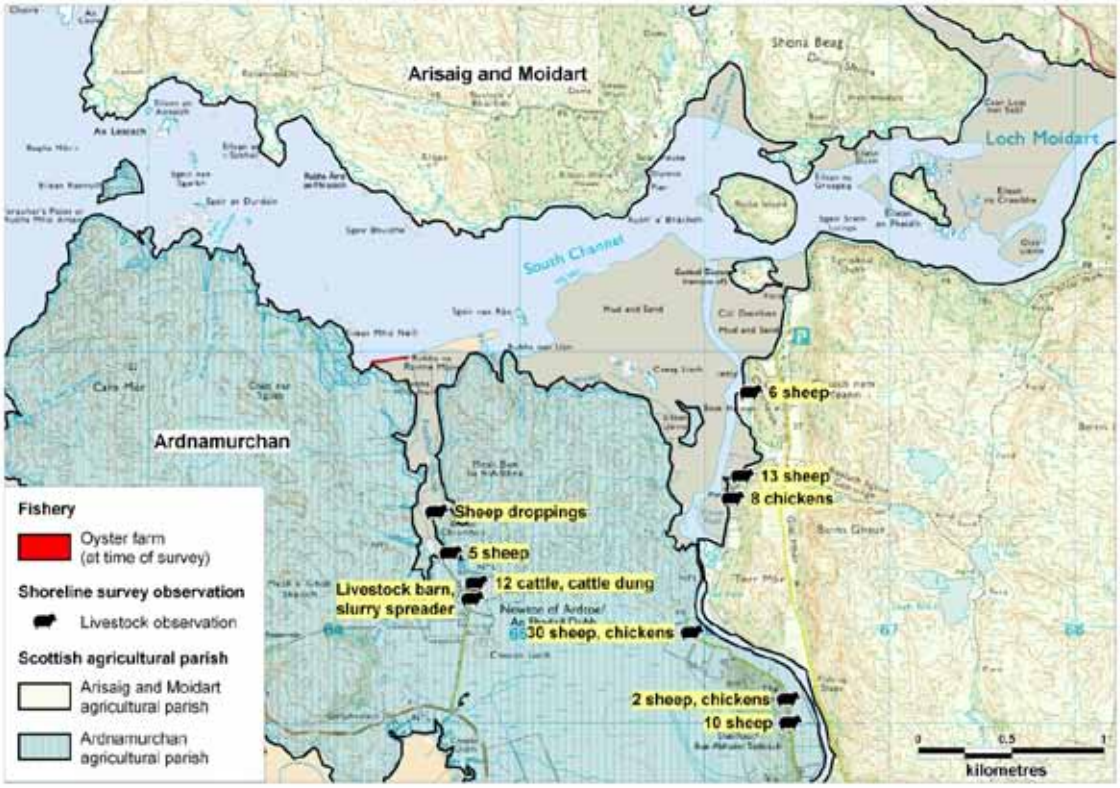

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Figure 7.1 Livestock observations at Loch Moidart

8. Wildlife

Wildlife may contribute to faecal contamination observed at fisheries. General information on the impacts of wildlife species can be found in Appendix 2. Wildlife species most likely to contribute to faecal contamination of the waters of Loch Moidart include birds, deer, and otters.

There are several specially designated sites in the area surrounding Loch Moidart. Loch Moidart Site of Special Scientific Interest (SSSI) was designated for structural and metamorphic geology, habitats and a beetle species (http://apps.sepa.org.uk/shellfish/pdf/34.pdf). Loch Shiel Special Protected Area (SPA) supports 2.5% (4 pairs) of the GB breeding population of Black-throated Divers (*Gavia arctica*). Loch Moidart is also part of the Sound Of Arisaig (Loch Ailort to Loch Ceann Traigh) Special Area of Conservation (SAC). Both the North Channel and the South Channel are included under the designation for internationally habitat of subtidal sandbanks. Kentra Bay and Moss SSSI located along the coastline south of the fishery was designated due to important terrestrial and saltmarsh features (http://www.snh.org.uk/pdfs/publications/commissioned_reports/commissionedcommissi074.pdf)

Birds

Results from the Seabird2000 census (Mitchell *et al*. 2004) were used to ascertain the likely distribution and numbers of seabirds at or near the Loch Moidart production area. Records within 5 km of the oyster farm are listed in Table 8.1.

Table 8.1 Seabird counts within 5km of the Loch Moidart shellfish farm

Common name	Species	Count	Method
Herring Gull	*Larus argentatus*	158	Occupied territory or nests
Common Gull	*Larus canus*	2	Occupied nests
Great Black-backed Gull	*Larus marinus*	19	Individuals on land/Occupied nests

Records showed an estimated total 179 seabirds within a 5km radius of the fishery. The distribution of these relative to the oyster farm is shown in Figure 8.1. The closest observation is located on a small island approximately 600 m north east of the fishery, where a large number of nesting herring gulls were recorded. Faecal wastes carried from this area in rainfall runoff are likely to contribute to background levels of faecal contamination at the oyster farm, particularly on the ebb tide. Herring gulls commonly lay clutches of eggs in May, with the chicks hatching in June (Mitchell, et al. 2004). Chicks fledge after 6 weeks (http://www.seabird.org/birds-herring-gull.asp, Accessed 02/05/12). These birds are likely to remain within the area year-round, returning to nest each spring, therefore impact from the nesting area is likely to be highest from May to August.

Other birds likely to be present in the area include geese, ducks and wading birds. Approximately 50 oyster catchers and 30 gulls were seen during the shoreline survey. No other data was obtained regarding the likely numbers

and distribution of these types of birds, however. The large intertidal areas around Faodhail Dubh and the mouth of the River Shiel are likely to host populations of wading birds during at least some of the year, with some species, such as oyster catchers, likely to be present throughout the year.

Birds flying over or feeding in waters at the fishery may directly deposit droppings near the oyster bags and so would have a greater impact on water quality when this occurs. Some species, such as gulls, are likely to be present year round and may rest on the farm equipment. Shore birds, such as oystercatchers, may breed in the area and some species are likely to be present year round. These may also deposit droppings in intertidal areas at or near the oyster bags.

During the shoreline survey small numbers of seabirds including gulls, geese and oystercatchers were observed, the distribution of which are shown in Figure 8.1.

Seals

Both grey seals (*Halichoerus grypus*) and common or harbour seals (*Phoca vitulina vitulina*) are recorded in western Scotland. Seals have been observed in this area in the past however there are no recorded sightings in recent years. As these animals may range widely for food, it should be presumed that they may be present in the area from time to time. No seals were observed during the shoreline survey.

Deer

Deer are present throughout much of Scotland in significant numbers. The Deer Commission for Scotland (DCS) conducts counts and undertakes culls of deer in areas that have large deer populations. The most recent year for which cull data was available was 2006. In the Ardmurchan and Moidart region, approximately 682 red deer, roe deer and sika deer were culled in the area in 2006. No information was available on distribution and numbers of live deer in the vicinity of Loch Moidart.

Faecal indicator bacteria arising from deer droppings are likely to be carried via rainfall runoff to rivers and streams. No deer or evidence of deer was observed during the shoreline survey.

Otters

Otters have been recorded in the area in the past, however no specific records of otter numbers were available. No otters were seen during the shoreline survey.

Otters typically defecate in established latrines adjacent to freshwater courses. Loch Moidart has a number of streams and burns that may host otters, and any faecal contamination from these animals is likely to be carried in the streams. Typical population densities of coastal otters are low and therefore any impact is expected to be minor and most likely to occur at the head of the bay.

Conclusions

Wildlife are likely to contribute to background levels of faecal contamination in the area. Wading birds and gulls may contribute droppings to the intertidal areas near the oyster farm when they are exposed. Any impacts from deer and otters are likely to be carried via watercourses to the loch.

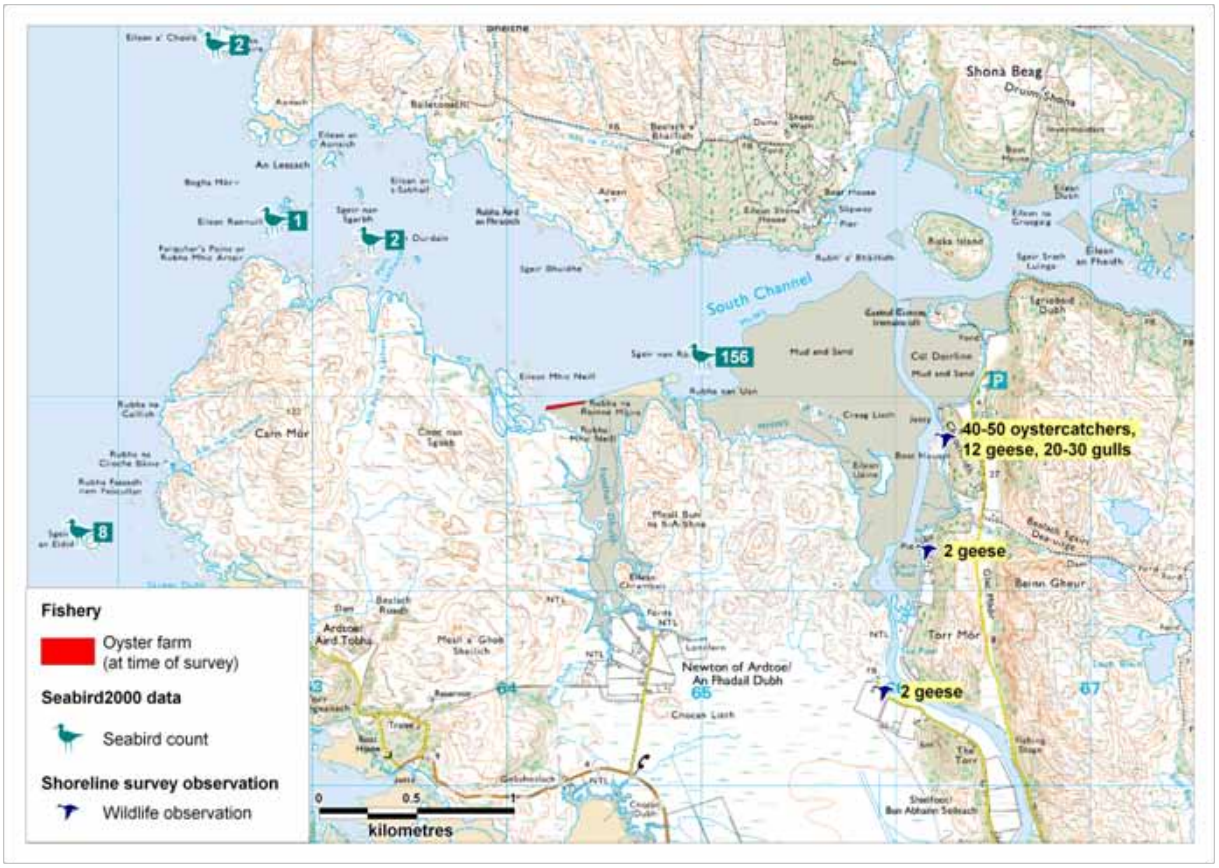

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Figure 8.1 Map of seabird distributions within 5 km of Loch Moidart

9. Meteorological data

The nearest weather station is located at Inverailort, approximately 16 km north east of the production area. Rainfall data was available for 2003 - 2010 however data was missing for January 2005, October – December, 2006 and October – December, 2010.

Wind data was available for Tiree, which is 70 km west of the fishery. Conditions may differ between this station and the fisheries due to the large distances between them. However, this data may still be useful in identifying seasonal variation in wind patterns.

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

9.1 Rainfall

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

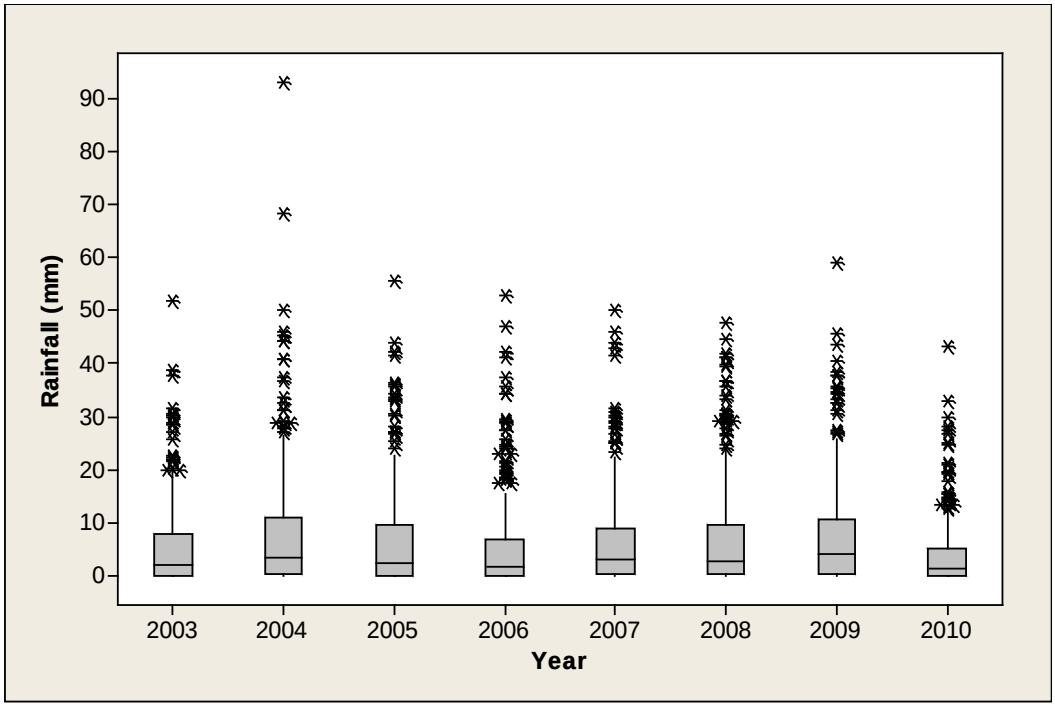

Figure 9.1 Daily rainfall values by year (2003 – 2010) at Inverailort.

Daily rainfall varied from year to year, and although 2006 and 2010 appeared to be dryer this may be due to missing data from October – December in these years.

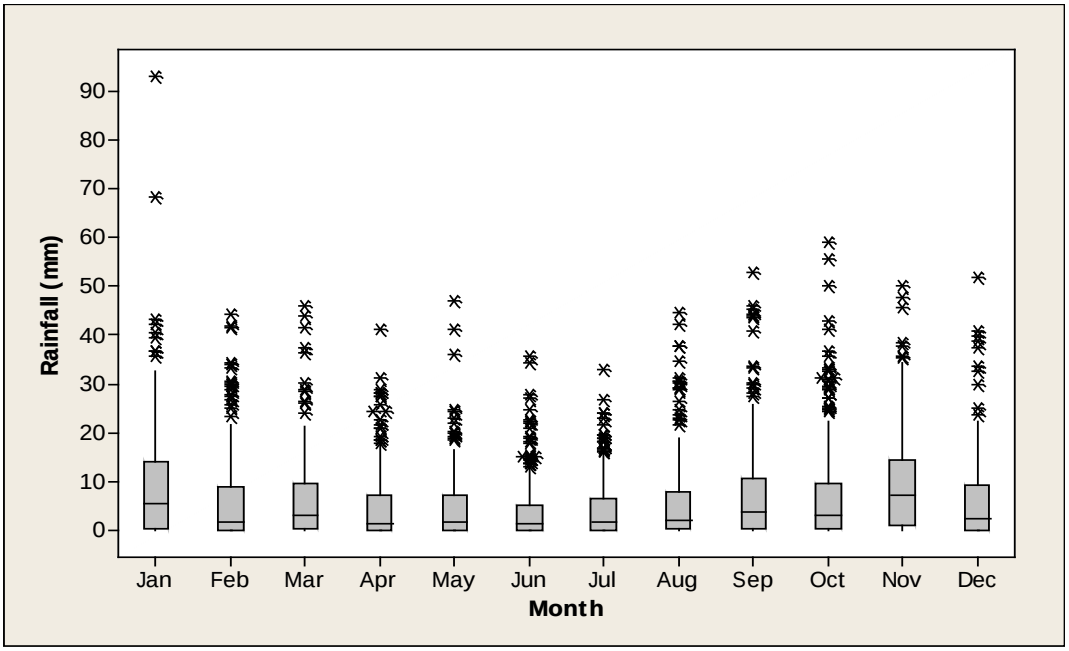

Figure 9.2 Daily rainfall values by month from 2003 – 2010 at Inverailort.

Weather was appeared to be wetter in the autumn and winter months with January and November showing to have the highest rainfall. Extreme rainfall events (>20mm) occurred throughout all the months and overall for the period considered here, 39% of days incurred rainfall of less than 1mm and 22% of days incurred rainfall of more than 10 mm. However, caution should be

exercised in interpretation of this data due to the large periods of missing data during what would normally have been a wet period (October-December).

It is therefore expected that run-off due to rainfall will be higher during the autumn and winter months. However, extreme rainfall events leading to episodes of high runoff can occur in most months and when these occur during generally drier periods in summer and early autumn, they are likely to carry higher loadings of faecal material that has accumulated on pastures when greater numbers of livestock were present.

9.2 Wind

Wind data was collected at Tiree and is summarised below in seasonal wind roses shown in Figure 9.3 and annually in Figure 9.4.

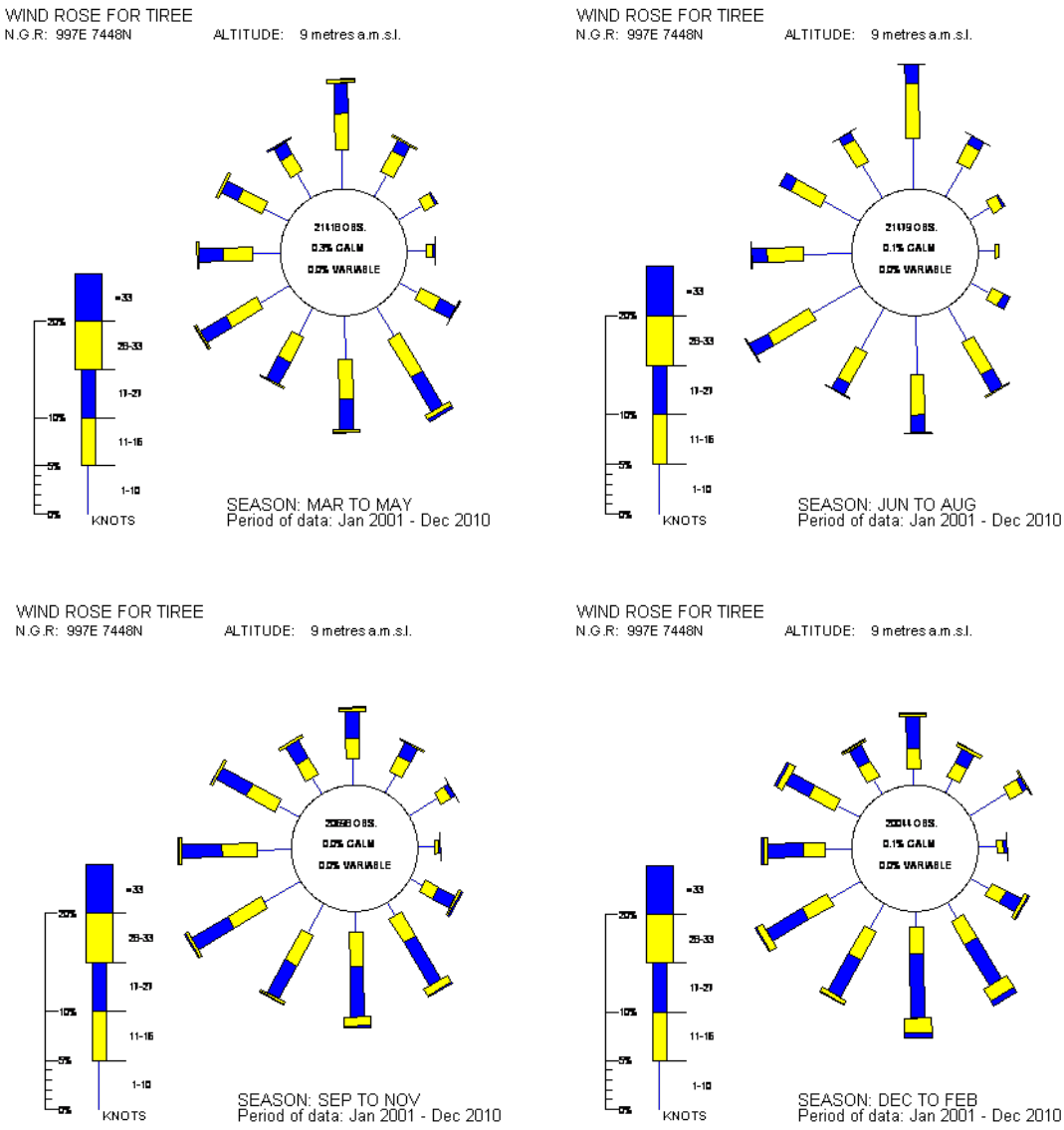

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Figure 9.3 Seasonal wind roses for Tiree

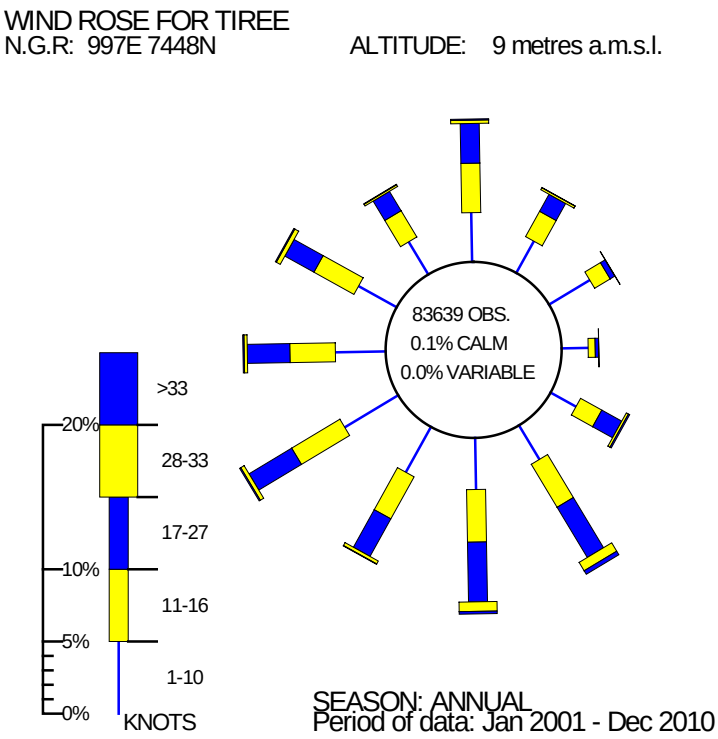

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Figure 9.4 Annual wind rose for Tiree

Overall, winds are predominantly from the south and southwest. There was little seasonal variation in wind direction, however winds were much stronger in the winter months than in the summer months.

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 surface movement at Loch Moidart. 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. Strong winds will increase the circulation of water and hence dilution of contamination from sources within the voe.

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10. Current and historical classification status

Loch Moidart was first given a classification for Pacific Oysters (*Crassostrea gigas*) in 2004. The historic and current classifications for the area are shown below in table 10.1.

Table 10.1 Loch Moidart, Pacific Oysters

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
2004	A	A	A	B	B	B	B	A	A	A	A	A
2005	A	A	A	A	A	A	B	B	B	B	B	B
2006	A	B	B	B	B	B	B	B	A	A	A	A
2007	A	B	B	B	B	B	B	B	A	A	A	A
2008	A	A	A	A	A	B	B	B	B	B	B	B
2009	A	A	A	A	A	B	B	B	B	A	A	A
2010	A	A	A	A	A	B	B	B	B	A	A	A
2011	A	A	A	A	A	B	B	B	B	A	A	A
2012	A	A	A									

Loch Moidart has held seasonal A/B classifications throughout its classification history. The area has been Class B for June, July, and August in most years.

11. Historical *E. coli* data

11.1 Validation of historical data

The results for all samples assigned against Loch Moidart from 1st January 2007 up to the 31st December 2011 were extracted from the FSAS database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. The data was extracted from the database in April 2012. All *E. coli* results were reported as most probable number per 100 g of shellfish flesh and intravalvular fluid.

Two samples were recorded on the database as "Rejected" and were deleted. Three samples were received at the laboratory >24 hours after collection, however none exceeded 48 hours. Most of the reported coolbox temperatures were within the recommended range of 2 and 8°C, however, five samples had reported coolbox temperatures of 1°C. Six samples were recorded from a location that fell outwith, but within 20 metres of the production area boundary. These were included in the analysis. Three samples had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation. No sample had a result reported as >18000.

11.2 Summary of microbiological results

Table 11.1 Summary of historical sampling and results

Sampling Summary	
Production area	Loch Moidart
Site	South
Species	Pacific oysters
SIN	HL 179 227 13
Location	Various
Total no of samples	41
No. 2007	4
No. 2008	7
No. 2009	10
No. 2010	10
No. 2011	10
Results Summary	
Minimum	<20
Maximum	5400
Median	140
Geometric mean	122.6
90 percentile	790
95 percentile	1400
No. exceeding 230/100g	13
No. exceeding 1000/100g	4
No. exceeding 4600/100g	1
No. exceeding 18000/100g	0

11.3 Overall geographical pattern of results

The majority of sample locations were recorded to 1m accuracy, though seven sample locations recorded during 2007 and 2008 were recorded to 100 m accuracy. Six of these were assigned to a location near the northern shore of the production area. At the time of sampling, this location was identified as the nominal RMP. However, discussion with the sampling officer and harvester confirmed that no oyster samples came from this location, and that the samples would have come from the south shore where the oyster farm is located. Most samples were taken at or near the current nominal RMP for the area, which lies higher up the shore than the oyster farm as recorded during the shoreline survey.

The reported sampling locations are plotted on the map shown in Figure 11.1 with the size of the symbols graduated by the size of the *E. coli* result.

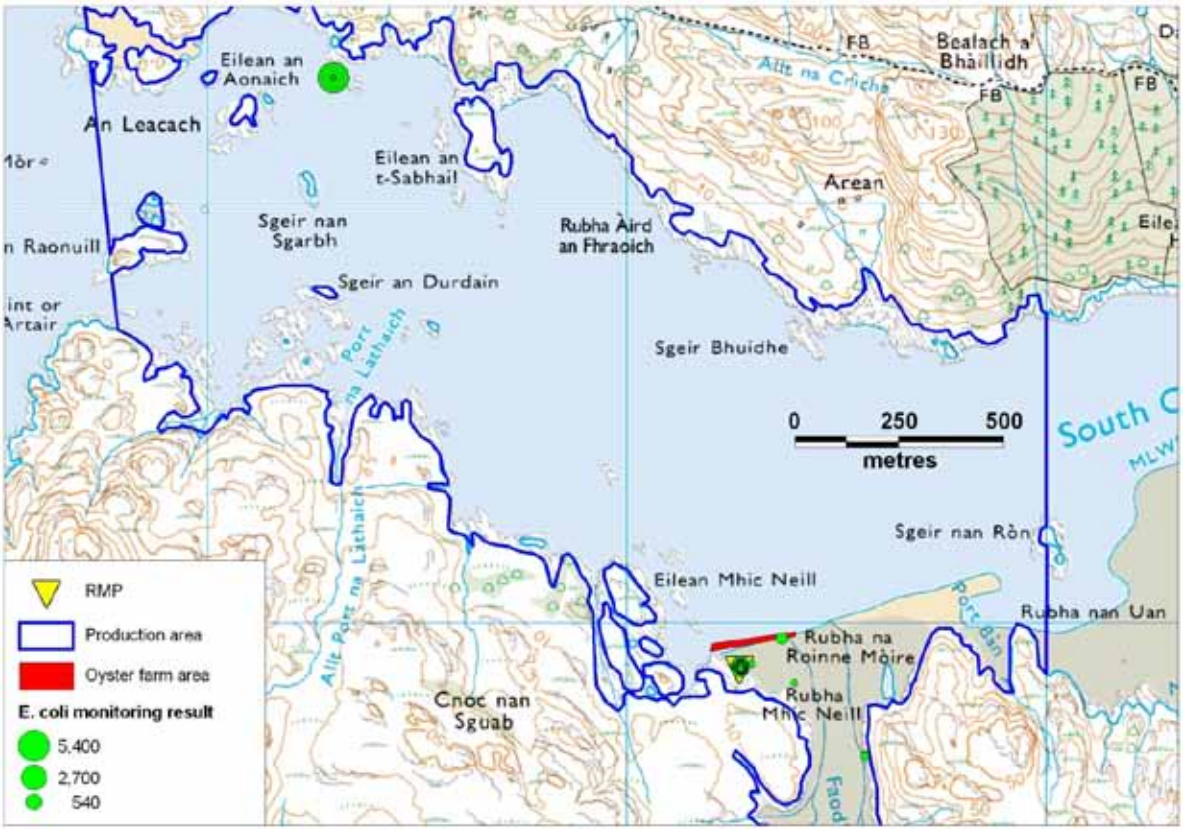

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Figure 11.1 Sampling locations and *E. coli* monitoring results at Loch Moidart

As the samples assigned to the old RMP at the north shore would have come from somewhere near the current oyster fishery, and most of the remaining samples have come from the current RMP, it was not possible to assess geographic variation in sampling results.

11.4 Overall temporal pattern of results

The scatter plot presented in 11.2 shows individual *E. coli* results against date, fitted with a loess smoother line. Loess stands for 'locally weighted regression scatter plot smoothing'. At each point in the data set an estimated value is fit to a subset of the data, using weighted least squares. The approach gives more weight to points near to the x-value where the estimate is being made and less weight to points further away. In terms of the monitoring data, this means that any point on the loess line is influenced more by the data close to it (in time) and less by the data further away. The smoother line helps to highlight any apparent underlying trends or cycles.

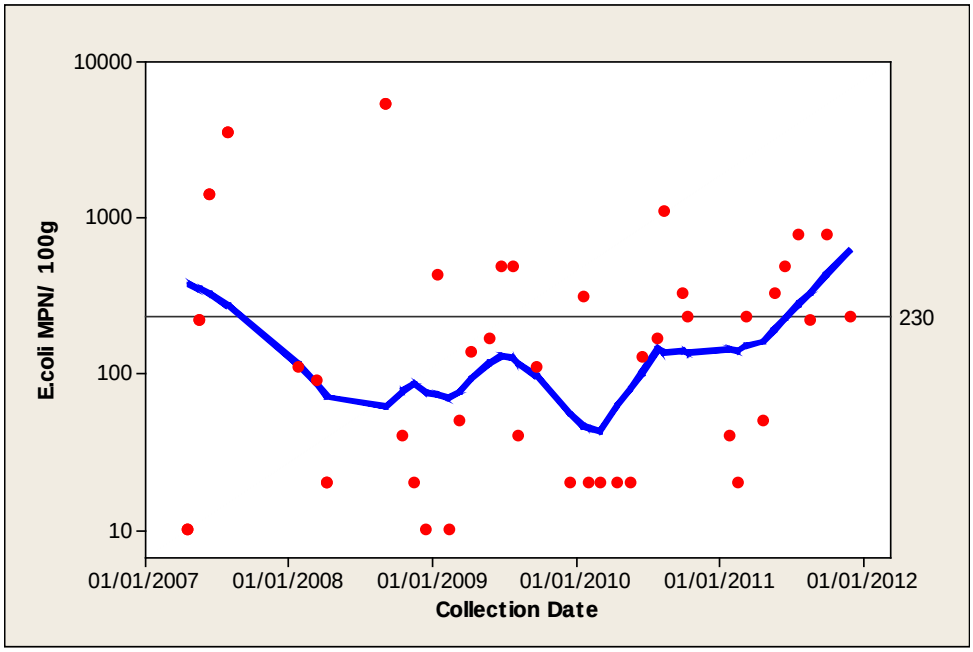

Figure 11.2 Scatterplot of *E. coli* results by date

Two results greater than 1000 *E. coli* MPN/100 g in early 2007 resulted in a high trendline at the beginning of the period, which then dropped before a steady rise from 2010 onward. Few results were at or below the limit of detection of the MPN test, though a series of low results in early 2010 resulted in a dip in the trend. From mid-2010 onward, the majority of results exceeded 230 *E. coli* MPN/100 g.

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 11.3 presents a scatterplot of *E. coli* result by month, overlaid with a loess line to highlight any trends. It should be noted that the points on the graph have been "jittered" (randomly moved a small distance in the X direction) to allow otherwise superimposed points to be seen separately.

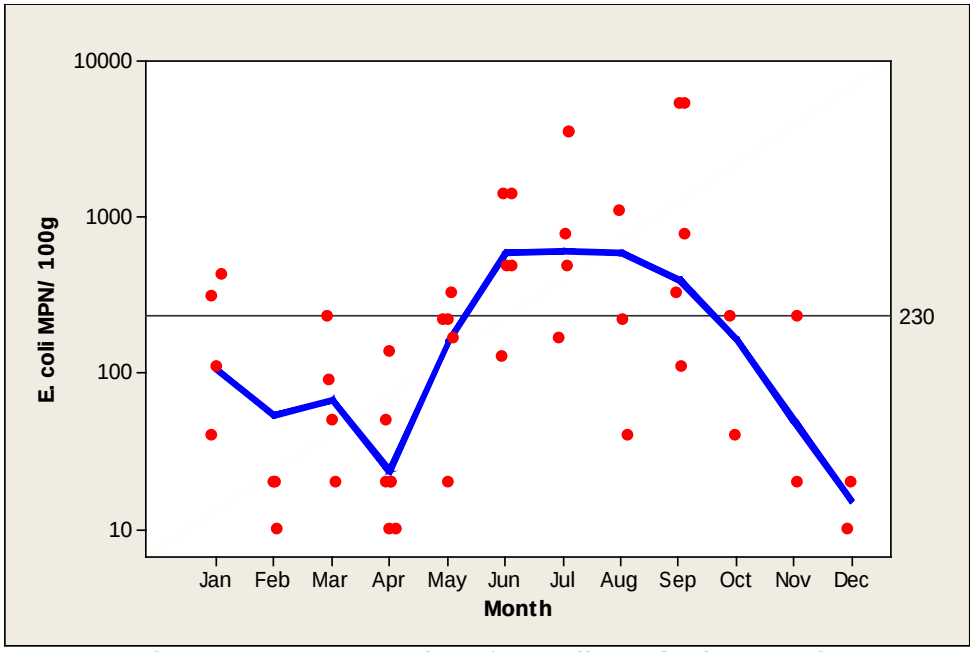

Figure 11.3 Scatterplot of *E. coli* results by month

A clear seasonal trend is apparent, with results tending to be lower in April and December and higher from June to September. Only 2 samples were taken in each of October, November and December.

For statistical evaluation, seasons were split into spring (March - May), summer (June - August), autumn (September - November) and winter (December - February). Boxplots of results by season are shown in Figure 11.4.

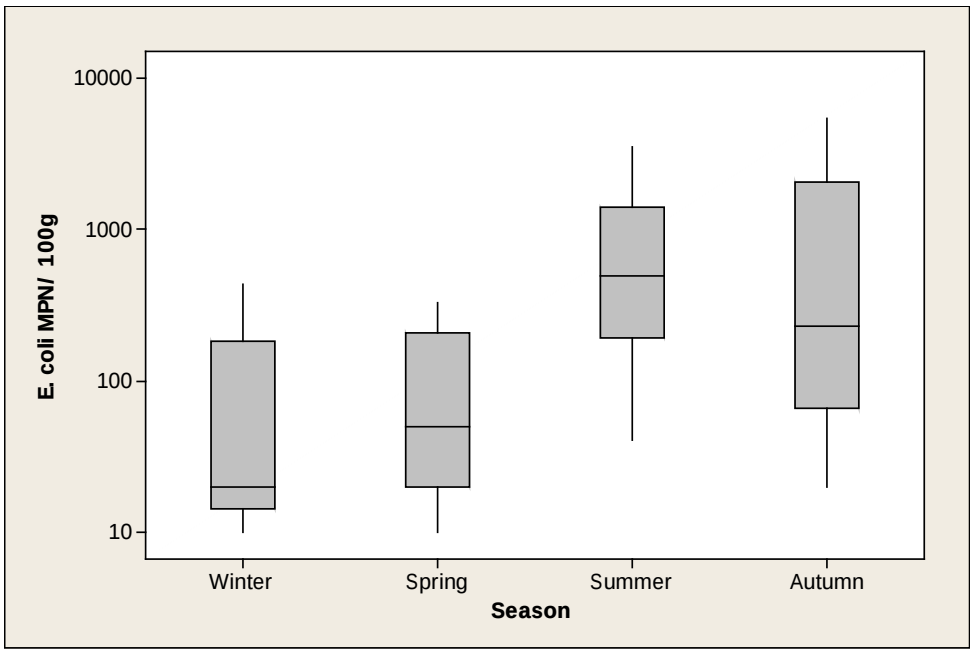

Figure 11.4 Box plot of results by season

A significant difference was found between results by season, with results in spring and winter lower than summer and autumn (One-way ANOVA, p = <0.001, Appendix 4).

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 for which rainfall was available was at Ardgour: Clovullin, approximately 9.4 km to the north west of the production area. Rainfall data was purchased from the Meteorological Office for the period 1/1/2002 to 31/12/2010 (total daily rainfall in mm). Data was extracted from this for the period 1/1/2007 to 31/12/2010.

The nearest weather station for which rainfall was available was at Inverailort, approximately 16 km to north east of the production area. Rainfall data was purchased from the Meteorological Office for the period 1/1/2002 to 31/10/2010 (total daily rainfall in mm). Data was extracted from this for the period 1/1/2007 to 31/12/2010. Rainfall data was not available for 12/10/2010 and therefore that the sample taken on that date was excluded from this analysis.

Two-day antecedent rainfall

Figure 11.5 presents a scatterplot of *E. coli* results against total rainfall recorded on the two days prior to sampling.

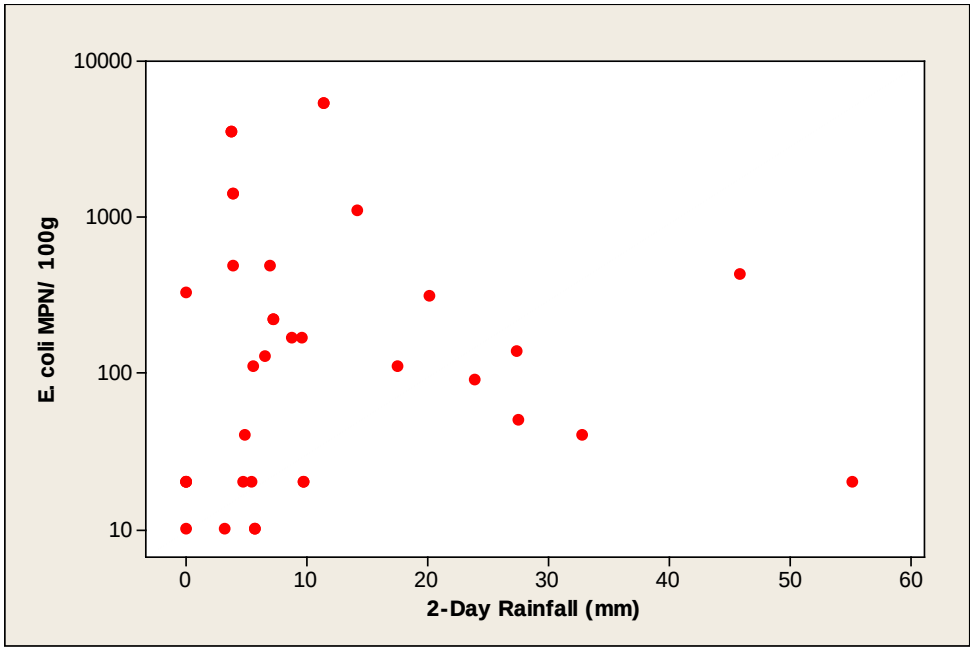

Figure 11.5 Scatterplot of result against rainfall in previous 2 days

No statistically significant correlation was found between two day rainfall and *E. coli* (Spearman's Rank correlation = 0.147, p = 0.392). However, very low results only occurred when 2-day rainfall was 10mm or less.

Seven-day antecedent rainfall

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. Figure 11.6 presents a scatterplot of *E. coli* results against total rainfall recorded on the seven days prior to sampling.

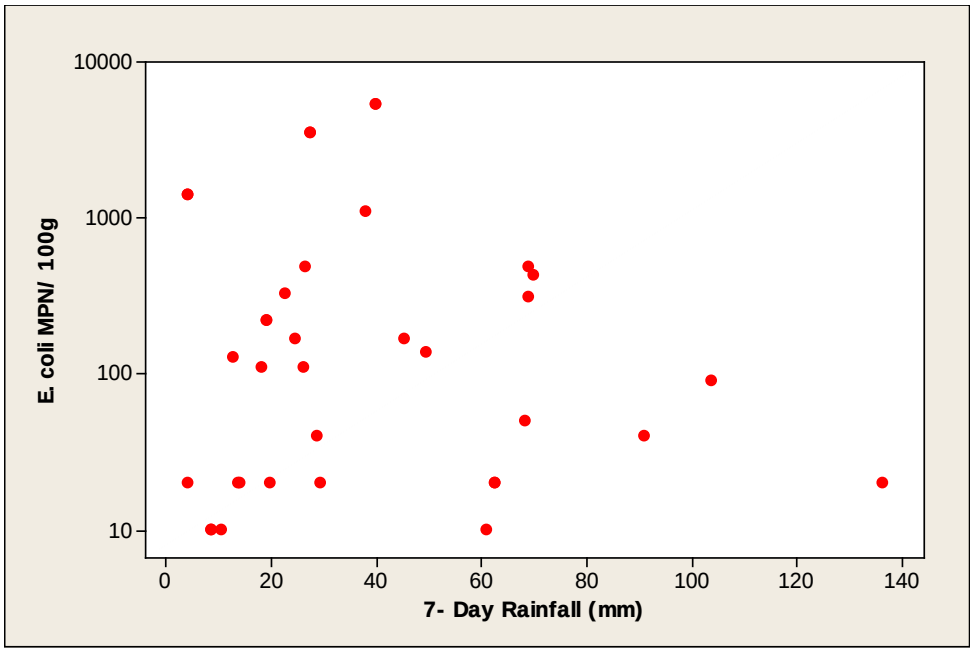

Figure 11.6 Scatterplot of result against rainfall in previous 7 days

No statistically significant correlation was found between *E. coli* and previous seven day rainfall (Spearman's Rank correlation = 0.101, p = 0.556).

11.6.2 Analysis of results by tidal height and state

Spring/Neap tidal cycle

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 area. Figure 11.7 presents a polar plot of $\log_{10}$ *E. coli* results on the lunar spring/neap tidal cycle. Full/new moons are located at 0º, and half moons at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. It should be noted that local meteorological conditions such as wind strength and direction can influence the height of tides and this is not taken into account.

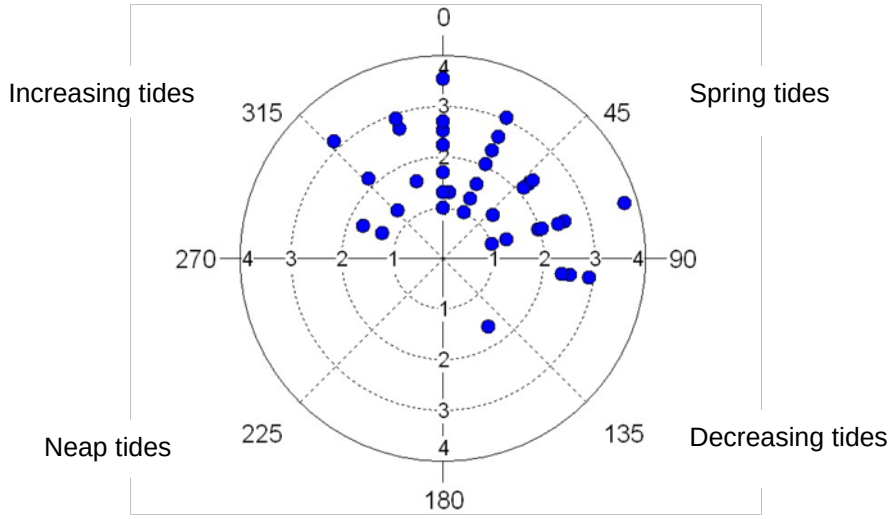

Figure 11.7 Polar plot of log_{10} *E. coli* results on the spring/neap tidal cycle

There was no significant correlation between *E. coli* results and the spring/ neap tidal cycle (Circular linear correlation = 0.083, p = 0.771). The majority of samples were taken slightly prior to, at, or slightly after spring tides.

High/Low tidal cycle

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the farms during this cycle. As *E. coli* levels in some shellfish species can respond within a few hours or less to changes in *E. coli* levels in water, tidal state at time of sampling (hours post high water) was compared with *E. coli* results. Figure 11.8 presents a polar plot of log_{10} *E. coli* results on the lunar high/low tidal cycle. High water is located at 0º, and low water at 180º.

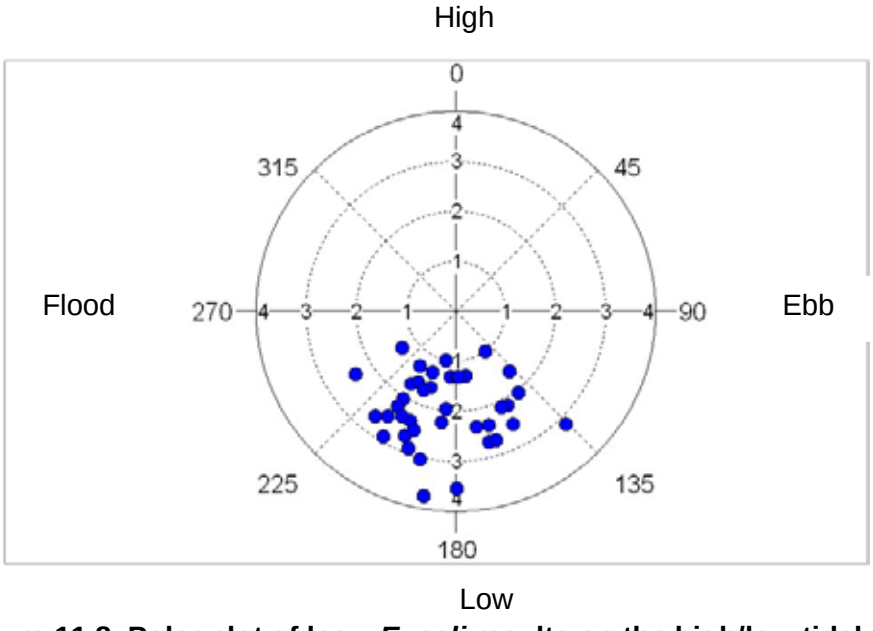

Figure 11.8 Polar plot of log_{10} *E. coli* results on the high/low tidal cycle

There was no significant correlation between *E. coli* results and the high/ low tidal cycle (Circular linear correlation = 0.014, p =0.993). Most samples were taken around low tide.

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. Water temperature was recorded against 26 of the sampling occasions. Figure 11.9 presents a scatterplot of *E. coli* results against water temperature recorded at the time of sampling.

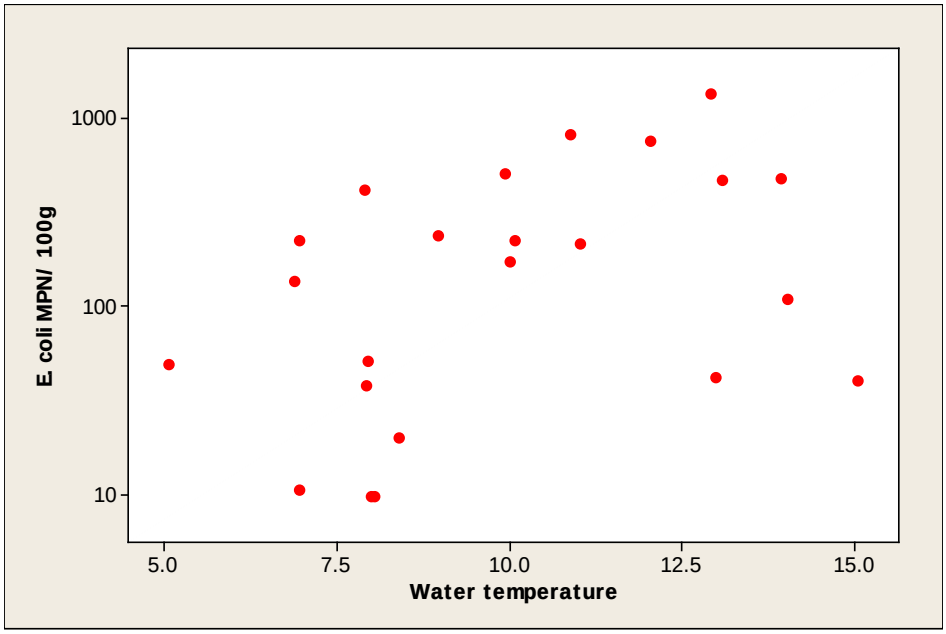

Figure 11.9 Scatterplot of result by water temperature

There was no statistically significant correlation between water temperature and levels of *E. coli* (Spearman's rank correlation = 0.406, p = 0.054). Samples were taken across a broad range of water temperatures, and very low sample results occurred only at water temperatures below 9°C.

11.6.4 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence, and hence freshwater borne contamination, at the site. A scatterplot of *E. coli* results against salinity is shown in Figure 11.10.

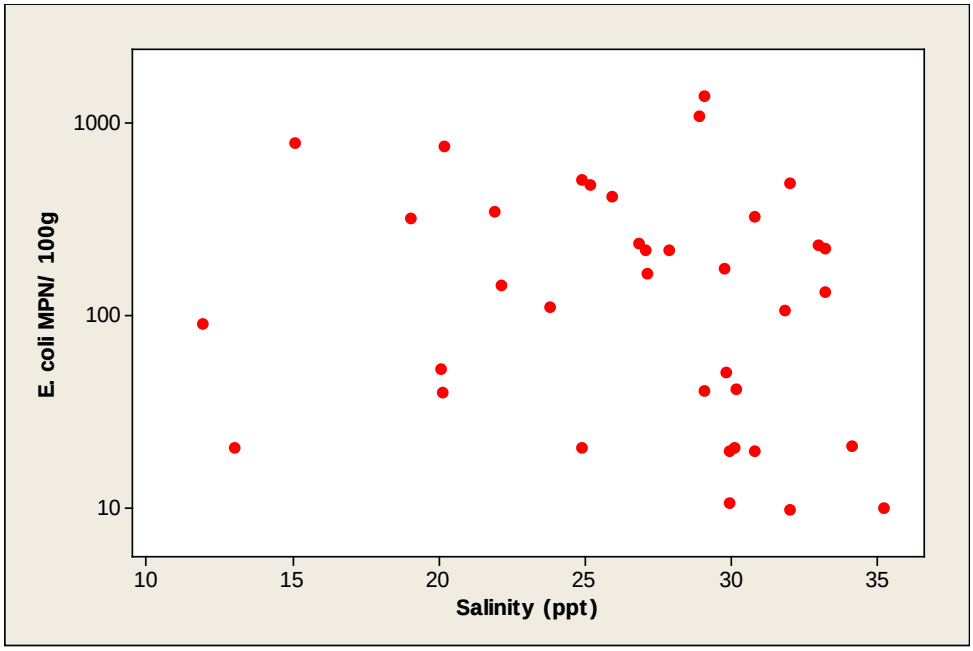

Figure 11.10 Scatterplot of result by salinity

Salinity was recorded for 37 of the 41 sampling occasions. A wide range of salinities was recorded, ranging from 12 to 35 ppt. The majority of samples were taken at salinities between 25 and 35 ppt. There was no significant correlation between *E. coli* and salinity (Spearman's rank correlation = -0.263, p =0.115).

11.7 Evaluation of results over 1000 *E. coli* MPN/100 g

Four results of greater than 1000 *E. coli* MPN/100 g were recorded in the historical sampling data analysed. Table 11.2 presents details of these samples.

Table 11.2 Historic *E. coli* sampling results over 1000 *E. coli* (MPN/100 g)

Collection date	*E. coli* (MPN/ 100 g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tidal state (high/ low)	Tidal state (spring/ neap)
14/06/2007	1400	a	3.9	3.9	13	29	ebb	increasing tide
30/07/2007	3500	a	3.7	27.4	*	*	low	increasing tide
02/09/2008	5400	a	11.4	39.6	*	*	low	decreasing tide
11/08/2010	1100	NM 64271 71897	14.2	37.9	*	29	low	increasing tide

* Data not available
a. Misattributed to incorrect RMP location

Three of these occurred when samples were being reported against an incorrect nominal RMP that plotted on the north shore of the loch. Salinity was only recorded for two of the samples, and both were 29 ppt, despite one

having been taken after a period of very low rainfall and the other after a period of moderate rainfall.

11.8 Summary and conclusions

The overall temporal trend in results appears to be upward. Although the highest results overall occurred prior to 2009, the majority of results from mid-2010 onward exceeded 230 *E. coli* MPN/100 g.

There was a clear seasonal trend in the monitoring data, with results tending to be higher from June to September. When examined by season, results in winter and spring were found to be significantly lower than in summer and autumn.

No statistically significant correlation between *E. coli* results and rainfall, tidal state, water temperature, or salinity was found. Most results were reported at between 25 and 35 ppt, indicating that the area is subject to significant freshwater influence.

Due to the intertidal nature of the fishery, most samples were taken at or near low water and on increasing to spring tides and assessment of correlation with the tidal cycles is therefore limited.

11.9 Sampling frequency

When a production area holds a non-seasonal classification and the geometric mean of the results falls within a certain range, the EURL Good Practice Guide (GPG) recommends that consideration be given to the sampling frequency being decreased from monthly to bimonthly. The recommendations are based on regular sampling having taken place and an initial three year data set of 24 results. As the area currently holds a seasonal classification an assessment was not undertaken.

12. Designated Shellfish Growing Waters Data

The Loch Moidart production area lies within the Loch Moidart, South Channel designated shellfish growing water. The area was designated under the European Community Shellfish Waters Directive (2006/113/EC) in 2002. SEPA is responsible for ensuring that monitoring is undertaken for a variety of parameters, including faecal coliforms in shore mussels.

Results of shellfish monitoring to 2005 were provided by SEPA and are presented in Table 12.1. The relative positions of the SGW boundary, the Loch Moidart production area, the nominal RMP, the fishery and the SGW monitoring points are shown in Figure 12.1.

Table 12.1 SEPA monitoring results for common mussels – Loch Moidart

Year	Quarter	Faecal coliform results (FC/100g)	
		Loch Moidart S (1) NM 633 733	Loch Moidart S (2) NM 65000 72700
2002	Q4	110	-
2003	Q1	40	-
	Q2	-	-
	Q3	-	3500
	Q4	-	90
2004	Q1	-	220
	Q2	-	1700
	Q3	-	1700
	Q4	-	40
2005	Q1	-	<20
	Q2	-	160
	Q3	-	70
	Q4	-	20

- No result reported

Samples were taken for faecal coliform analysis from two points within the growing waters. The first monitoring point sampled was located 1.6 km north west of the current production area and coincides with an old nominal RMP. The second monitoring point is located 0.9 km north east of the current fishery in the line with the production area eastern boundary. The geometric mean result for samples taken from this monitoring point is 190 FC/100 g. Results ranged from <20 to 3500 FC/100 g, indicating intermittently high levels of faecal contamination at this location.

Although levels of faecal coliforms in shellfish are usually correlated to levels of *E. coli* at a ratio of roughly 1:1, the ratio depends on a number of factors, such as environmental conditions and the source of contamination. Comparison is further complicated by differences in accumulation between the different bivalve species. Consequently, the results present in Table 12.1 are not directly comparable with the other shellfish testing results presented in this report.

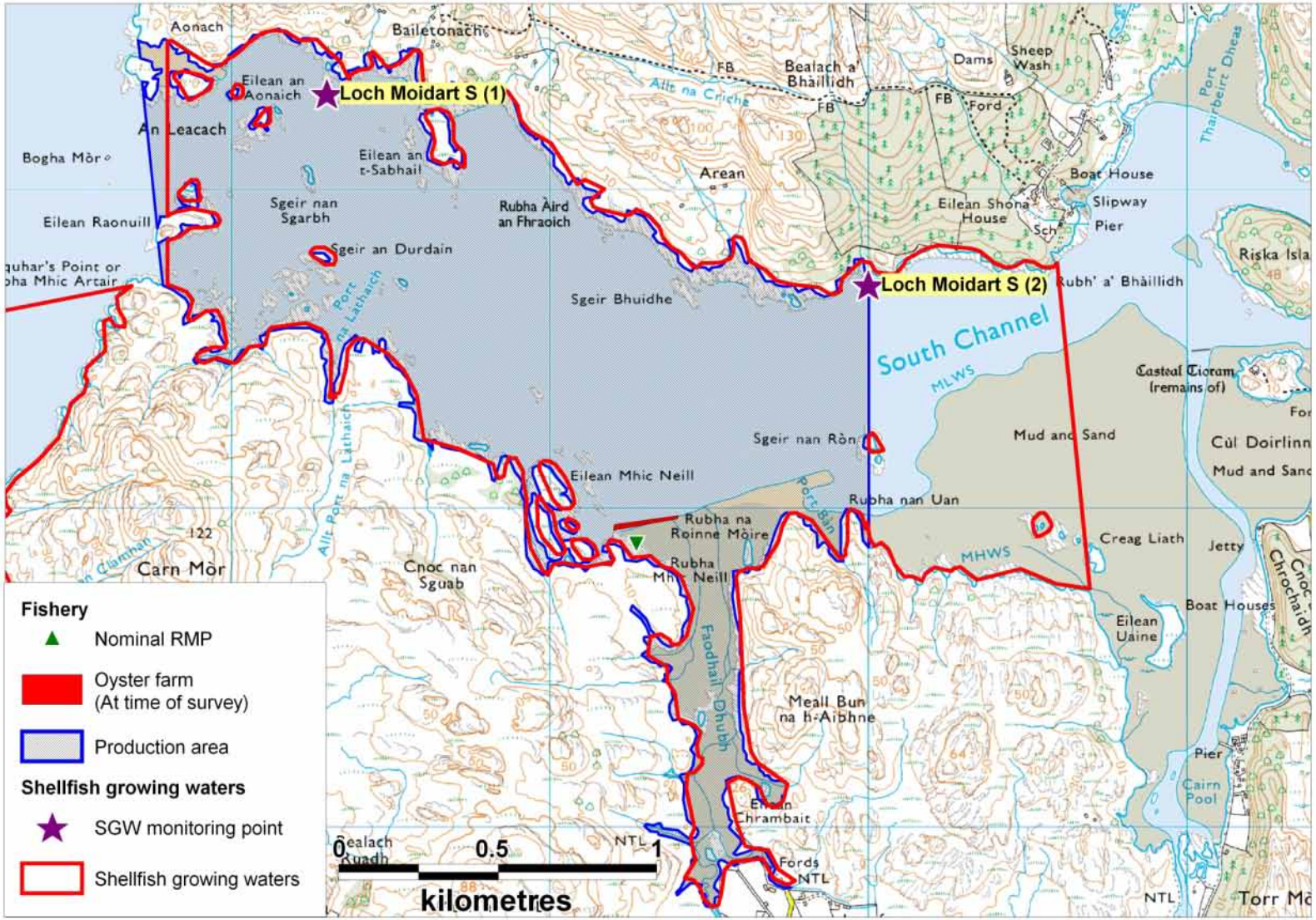

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Figure 12.1 Designated shellfish growing water – Loch Moidart

13. River Flow

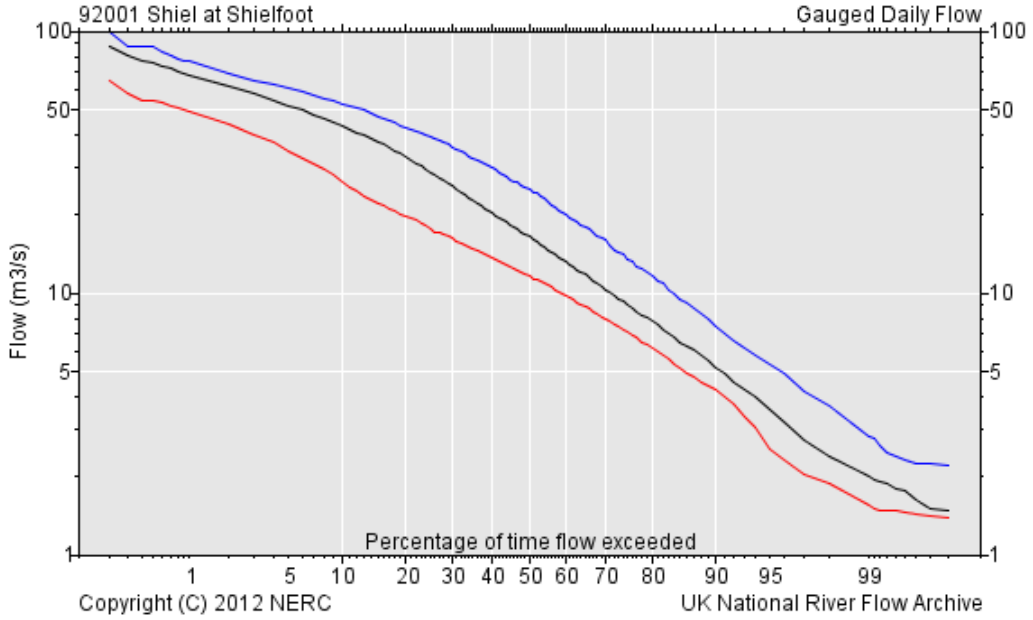
There is one river gauging station in the vicinity of Loch Moidart on the River Shiel at Shielfoot (http://www.ceh.ac.uk/data/nrfa/data/station.html?92001). The river discharges into the South Channel of the loch, approximately 1.8 km east of the fishery. Data for the gauging station was supplied by CEH as daily averaged flows in m^3/s. These were multiplied up to m^3/day to allow comparison with the data from the shoreline survey. Summary statistics for the station is presented in Table 13.1. The flow duration curve from the National River Flow Archive is shown in Figure 13.1. The River Moidart cSAC Conservation Strategy identified that river level or flow monitoring of the River Moidart was desirable but no record was found of such equipment being installed (Birkeland, 2003).

Table 13.1 CEH river flow data (1995-2010) at the River Shiel, Shielfoot gauging station discharging to Loch Moidart

		Flow (m^3/day)*				
Station	Grid Reference	Minimum	Lower quartile	Median	Upper quartile	Maximum
River Sheil at Shielfoot	NM 66586 70178	1.05×10^5	7.79×10^5	1.42×10^6	2.50×10^6	9.35×10^6

*rounded to 3 significant figures. Data originally provided as daily averaged flow in m^3/s

The River Shiel was sampled during the shoreline survey and yielded a result of 200 *E. coli* cfu per 100 ml. The flow of the River Shiel on the date the water sample was taken was 5.15×10^5 m^3/day. This flow level is low when considered in light of the table above and would be expected to occur only 10% of the time, based on the duration curves in Figure 13.1.



Data from the CEH National River Flow Archive. Based on the period 1995-2010

Figure 13.1 Flow Duration Curves for gauged daily flow for the River Shiel, Shielfoot gauging station

The rivers and streams listed in Table 13.1 were measured and sampled during the shoreline survey. These represent the freshwater inputs to the southern channel of the loch in the vicinity of the fishery. There were moderate rain showers during the first part of the shoreline survey and heavy rain showers during the second half. The locations, together with the calculated loadings, are shown in Figure 13.2.

Table 13.2 River (or stream) loadings for Loch Moidart

No	Grid Ref	Description	Width (m)	Depth (m)	Flow (m/s)	Flow in m^3/day	*E. coli* (cfu/ 100 ml)	Loading (*E. coli* per day)
1	NM 66318 71436	Stream	0.35	0.05	0.247	373	<100	$<3.73x10^8$
2	NM 66318 71402	Stream	0.95	0.04	0.269	883	<100	$<8.83x10^8$
3	NM 64534 71559	Stream	4.3	0.08	0.225	6687	No sample	Not determined
4	NM 64557 70909	Stream	2	0.05	0.036	311	500	$1.8x10^5$
5	NM 67400 69178	River Shiel	6.5	2.7	0.34	515549	200	$1.03x10^{12}$
6	NM 64613 71153	Stream	1.83	4.5	0.093	66170	1000	$6.62x10^{11}$
7	NM 64623 70898	Stream	2.5	0.04	0.141	1218	7400	$9.01x10^{10}$

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Figure 13.2 Map of river/stream loadings at Loch Moidart

The watercourses identified as 1-7 in the table and map were sampled and measured on the 05/07/11 during rain showers, with no rain the previous 3

days and those identified as 8-10 were sampled and measured on 06/07/11, during moderate to heavy rain showers. Flows were higher during the second half of the survey.

In total three of the watercourses yielded *E. coli* results indicating marked faecal contamination. The streams identified as 9 and 10 both discharge into Faodhail Dhubh located < 1 km south of the fishery and had moderate *E. coli* loadings of 6.62×10^{11} and 9.01×10^{10} *E. coli* (cfu/100 ml) per day. The highest calculated loading of 1.03×10^{12} *E. coli* (cfu/100 ml) per day was recorded at the River Shiel located approximately 1.8 km east of the fishery. The conditions observed on the day of shoreline survey were representative of low flow conditions, and therefore loadings in the streams and river would be expected to increase significantly after rainfall.

There are other streams and rivers, including the River Moidart, identified on the OS map that were not observed or recorded during the shoreline survey.

Freshwater reaching the fishery from both the River Moidart and the streams at the head of Faodhail Dhubh are likely to significantly contribute to faecal contamination levels at the fishery.

14. Bathymetry and Hydrodynamics

Figure 14.1 shows the bathymetry at Loch Moidart with the detail in the vicinity of the oyster farm shown on the inset.

Loch Moidart is situated on the west coast of Scotland immediately to the north of the Ardnamurchan peninsula and lies in roughly an east to west direction. It is approximately 8 km in overall length. It is split into two channels by Eilean Shona. The oyster farm lies on the southern shore of the south channel, at the edge of a drying area on the western side of Faodhail Dhudh, a small bay that dries completely at low tide. There are other extensive drying areas: at the mouth of the River Shiel, much of the inner half of the loch (around the channel formed by the River Moidart), and around Shona Beag at the eastern end of Eilean Shona. There is a causeway allowing access to Shona Beag from the northern shore at low tide.

The Scottish Sea Lochs Catalogue (Edwards & Sharples, 1991) identifies one sill in the north channel and two sills in the south channel. One of the latter is located a short distance to the west of the oyster farm and the other is located on the south-eastern side of Eilean Shona, in the vicinity of the island of Riska.

In the south channel, depths at the outer edge of the oyster farm do not exceed 1 m but there are deeper areas exceeding 5 m further offshore. The maximum depth in the south channel is approximately 11 m; this occurs at the mouth of the channel. The maximum depth in the North Channel is approximately 18 m; this occurs in a basin in the centre of the channel. There are a number of small islands and rocky outcrops located at the mouth of the south channel. An anchorage is marked immediately to the east of these and small craft moorings are indicated to the east of Faodhail Dhubh.

14.1 Tidal Curve and Description

The two tidal curves below are for Loch Moidart itself. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 BST on 05/07/2011 and the second is for seven days beginning 00.00 GMT on 12/07/11. They cover the date of the shoreline survey. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle.

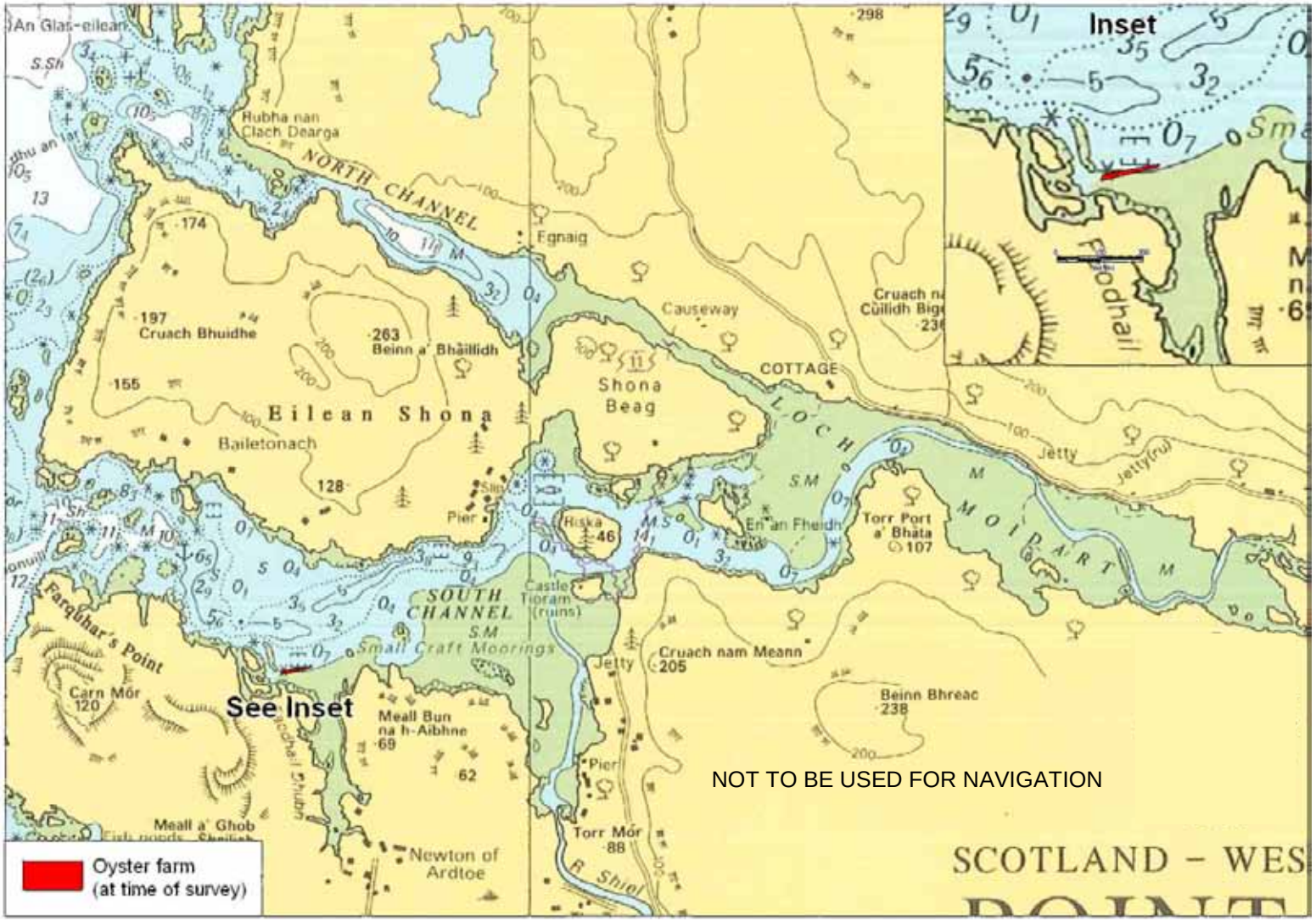

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Figure 14.1 Bathymetry at Loch Moidart

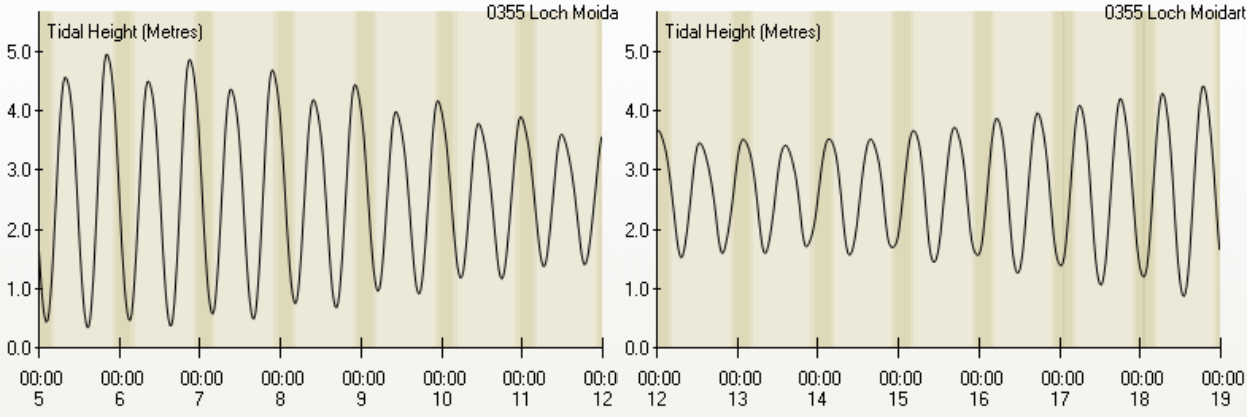

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Figure 14.2 Tidal curves for Loch Moidart

The following is the summary description for Loch Moidart from TotalTide:

The tide type is Semi-Diurnal.

HAT	5.4 m
MHWS	4.8 m
MHWN	3.5 m
MLWN	1.6 m
MLWS	0.5 m
LAT	-0.2 m

Predicted heights are in metres above chart datum.

The average tidal range at spring tide is 4.3 m and at neap tide it is 3.0 m. Loch Moidart is therefore macrotidal (large tidal range).

14.2 Currents

There are no tidal diamonds or other tidal stream information for the immediate vicinity of Loch Moidart. In addition, no information on current meter studies could be sourced from either SEPA or the British Oceanographic Data Centre (BODC).

In Section 14.1, it was identified that the loch is subject to a high tidal range. The Scottish Sea Lochs Catalogue gives the flushing time of the north channel as 1 day and that of the south channel as 0 days (Edwards & Sharples, 1991). It is therefore expected that currents in the loch will be significant during the flood and ebb tide although there is no information on which to basis an estimate of the likely speeds.

14.3 Salinity data

No salinity profiles were taken during the shoreline survey as the shellfishery was intertidal. Only two spot samples of seawater were taken during the shoreline survey. One, taken in the outer channel of the River Shiel, gave a

salinity result of 22.3 ppt, show an expected freshwater influence. The other, taken at the oyster farm, gave a salinity result of 35.2 ppt, essentially full strength seawater. The Scottish Sea Lochs Catalogue gives a calculated salinity reduction of 0.1 ppt for the north channel and 2.6 ppt for the south channel. The latter would be expected due to the significant freshwater inputs from the rivers Moidart and Shiel.

14.4 Conclusions

The south channel is relatively shallow and thus any contaminants will be subject to limited dilution. During the flood tide, the oyster farm will potentially be impacted by sources located towards, and outside the mouth of the south channel. During the ebb tide, the oyster farm will potentially be impacted by contamination arising towards the head of the loch, from the River Shiel and its estuary, and from within Faodhail Dhudh. Contamination that has been taken from sources in the north channel towards the head of the loch on the flood tide may be taken down the south channel on the ebb tide. As the ebb tide continues, the tendency will be for contamination from the head of the loch and from the River Shiel to be directed more into the main channel and thus may by-pass the oyster farm. Bags of oysters on the northern side of the present farm will be exposed to such contamination for a longer period than those towards the shore. If rafts are used in the future, the oysters will be further from sources of contamination at the adjacent shore but will be exposed to contamination from other sources on a continuous basis, with the impact depending on location of source and the direction of the current. The nature and extent of any contamination will depend on the location of the rafts.

15. Shoreline Survey Overview

The shoreline survey was conducted on the 5th and 6th July 2011 under variable weather conditions.

The Loch Moidart production area consists of a single Pacific oyster farm on the south shore of the loch. Oysters are grown in triangular bags suspended from ropes set at approximately one metre above the seabed and at or just below MLWS. A dedicated line was set in place for sampling purposes that held two baskets of oysters. This was set higher up the shore and was accessible across a wider range of tidal conditions. There was little to no stock available on the lines, as the harvester was in the process of clearing out to move production further offshore. Rafts will be put in place in the future, from which the triangular bags will be suspended. Harvesting may occur at any time of year.

A small number of homes were present at Ardtoe, to the south of the fishery. The majority of these were holiday lets. There were two homes in permanent occupation. A small number of properties were observed along the east shore of the River Shiel, many of which are thought to be in seasonal occupation. A cabin with a septic tank and discharge pipe was observed on the eastern shore, opposite the oyster farm. This cabin is in occasional use by the harvester.

Livestock including sheep and cattle were observed grazing at the head of the Newton of Ardtoe and the eastern shoreline of Faodhail Dhubh. In total approximately 66 sheep and 12 cattle were counted. There is a farm and evidence of the transportation of faecal wastes from livestock housing to on-farm storage or spreading on land. Sheep droppings were observed in the strand line and on the intertidal shore south of the fishery, particularly along the eastern shoreline of Faodhail Dhubh. A small number of chickens were also observed in the area.

Approximately, 40-50 oystercatchers, 20-30 gulls and 12 wild geese were observed in total along the River Shiel. Otherwise, no other significant aggregations of birds were observed. No other species of wildlife were observed.

A sea water sample taken within the vicinity of the fishery contained 100 *E. coli* (cfu/100 ml) and a sea water sample taken close to the estuary of the River Shiel contained 2900 *E. coli* (cfu/100 ml). The sea water sample taken close to the estuary had a low salinity reading of 22.3 ppt, indicating significant fresh water influence.

Freshwater samples and/or discharge measurements were taken at ten of the watercourses draining into the survey area. The streams were of varying size and drained areas of open grassland and heath land. It was not possible to sample four of the ten watercourses. Fresh water samples were taken from the remaining watercourses contained varying levels of *E. coli* contamination.

The highest fresh water result contained 7400 *E. coli* (cfu/100 ml) was taken from a stream at the head of Faodhail Dhubh.

Shellfish samples were collected from the two locations. An oyster sample was collected from the fishery and contained 80 *E. coli* (MPN/100 g) and a shore mussel sample collected 170 m south east of the fishery and contained 100 *E. coli* (MPN/100 g).

Figure 15.1 shows a summary map of the most significant findings from the shoreline survey for Loch Moidart.

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Figure 15.1 Summary of shoreline survey findings for Loch Moidart

16. Overall Assessment

Human sewage impacts

The overall the population density is low for the areas surrounding the south channel of Loch Moidart. The cabin located on the east side of Faodhail Dhubh has the nearest septic tank to the fishery. Water runoff from the roof appeared to drain into the septic tank, which would lead to increased flow through the septic tank, decreasing its efficiency. However, this cabin is not permanently occupied and therefore is only likely to be a small and intermittent source of contamination. Sewage discharges at the mouth of Faodhail Dhubh and at Newton of Ardtoe are likely to have a greater impact on the fishery as some of the homes are permanently occupied and water samples taken in the vicinity were relatively highly contaminated.

Possible intermittent discharges from boats near the fishery may also contribute faecal contamination as a number of small workboats were seen around the area, and there was a yacht on a mooring just offshore of the oyster farm at the time of survey.

A small number of dwellings are located along the east shore of the River Shiel, many of which are in seasonal occupation. A septic tank was observed and a seawater sample taken at the same location had a high result of 2900 *E. coli*/100 ml, indicating faecal content. The village of Acharacle, which lies further upriver, has a secondary treatment works that discharges to the river. This is likely to contribute to background levels of contamination at the fishery, and may contribute more significantly when any of the CSOs are operating.

Agricultural impacts

It is likely that a significant proportion of any faecal contamination reaching the fishery is from diffuse, livestock sources. Livestock had access to the shoreline and watercourses. Sheep droppings were observed in the strand line and on the intertidal shore south of the fishery. There is also the potential for direct runoff from the hillside to the south east of the fishery to carry livestock faecal material to the waters immediately east of the shellfish farm.

Cattle are kept on a farm at Newton of Ardtoe and wastes from winter housing may end up in the stream when the muck spreader is parked next to the stream.

Overall, the eastern side of the oyster farm is likely to be most impacted by these sources.

Wildlife impacts

Overall, the wildlife species most likely to be present in or around Loch Moidart are likely to be present in modest numbers and will contribute to background levels of contamination at the fishery. A colony of gulls located

to the east of the oyster farm will be a focus of contamination during the breeding season from May to August, after which the birds will be more widely dispersed around the area. Gulls and cormorants may rest on the ropes and bags throughout the year, and wading birds and gulls are likely to leave droppings on the intertidal shoreline. Deer are likely to be present in potentially large numbers within the catchment area, and are likely to contribute to faecal loadings recorded in watercourses discharging to Loch Moidart. Most of these will impact waters to the east and south of the oyster farm, and contaminants will be transported to the fishery on the outgoing tide.

Seasonal variation

Significant seasonal variation is likely to occur in livestock population numbers, as sheep production is prevalent in the area and the number of sheep would roughly double during the summer months when lambs are present. Significant seasonal variation was also observed in rainfall, with higher rainfall generally occurring during the autumn and winter. However, significant rainfall events during summer may have a higher impact on the fishery due to the first flush effect of accumulated livestock droppings being washed to the fishery via watercourses.

The human population in the area is likely to be higher in summer, as many dwellings in the area were only seasonally occupied.

There was a clear seasonal trend in the monitoring data, with results tending to be higher from June to September. When examined by season, results in winter and spring were found to be significantly lower than in summer and autumn.

Rivers and streams

Freshwater reaching the fishery from both the River Moidart and the streams at the head of Faodhail Dhubh are likely to significantly contribute to faecal contamination levels at the fishery. The streams discharging to the head of Faodhail Dhubh were found during the shoreline survey to carry significant loadings of faecal contamination, particularly considering their relatively small size. The River Moidart, while less contaminated, carried a higher loading due to its much higher flow. Both these watercourses were measured and sampled during low flow conditions, and therefore the loadings may be expected to increase under higher flow conditions.

The majority of salinity values recorded in historical monitoring data were below 35 ppt, which indicates that freshwater sources impact at the fishery much of the time. Though the amount of salinity reduction, and hence influence, was variable, most observations were recorded at between 25 and 35 ppt. Salinity values recorded for water samples taken during the shoreline survey showed no freshwater influence found nearer the oyster farm at that time.

Movement of contaminants

The south channel is relatively shallow and thus any contaminants will be subject to limited dilution. During the flood tide, the oyster farm will potentially be impacted by any sources arising to the west of Faodhail Dhubh and outside the loch. During the ebb tide, the oyster farm will potentially be impacted by contamination arising from sources toward the head of the loch, from the River Shiel and its estuary, and from within Faodhail Dhubh.

Contamination that has been taken from sources in the north channel towards the head of the loch on the flood tide may be taken down the south channel on the ebb tide. As the ebb tide continues, the tendency will be for contamination from the head of the loch and from the River Shiel to be directed more into the main channel and thus may by-pass the oyster farm. Bags of oysters on the northern side of the present farm will be exposed to such contamination for a longer period than those towards the shore. If rafts are used in the future, the oysters will be further from sources of contamination at the adjacent shore but will be exposed to that from other sources on a continuous basis, with the impact depending on location of source and the direction of the current. The nature and extent of any contamination will depend on the location of the rafts.

Temporal and geographical patterns of sampling results

The overall temporal trend in results appears to be upward. Although the highest results overall occurred prior to 2009, the majority of results from mid-2010 onward exceeded 230 *E. coli* MPN/100 g.

As the samples assigned to the old RMP at the north shore would have come from somewhere near the current oyster fishery, and most of the remaining samples have come from the current RMP it was not possible to assess geographic variation in sampling results.

Conclusions

The main sources of contamination to the oyster farm at Loch Moidart are agricultural and human sewage sources around Faodhail Dhubh to the south and along the River Moidart to the east. Wildlife are also likely to contribute significantly to background levels of faecal contamination at the fishery, particularly during the summer months when gulls are present at the breeding colony east of the oyster farm. The Rivers Moidart and Shiel are both likely to be significant pathways by which diffuse faecal contaminants are carried to the waters of the production area. The River Shiel also carries sewage discharges from the public treatment works at Acharacle and from a small number of private septic tanks. All known sources lie to the south and/or east of the fishery, and therefore the impacts are most likely to affect the east end of the farm first. Oysters placed lower on the shoreline or suspended under floats will be able to filter over a wider proportion of the tidal cycle.

17. Recommendations

Production area

Based on recorded sources of faecal contamination, it is recommended that the production area boundaries be curtailed to exclude the upper Foadhail Dhubh and areas nearer the River Sheil. The recommended boundaries are therefore the area bounded by lines drawn between NM 6490 7268 and NM 6494 7200 and between NM 6458 7179 and NM 6439 7179 and between NM 6347 7253 and NM 6338 7334 and extending to MHWS.

RMP

It is recommended that the RMP be relocated to NM 6439 7197, which lies nearer to sources to the east and southeast of the oyster farm.

Frequency

As the area currently holds a seasonal classification, and a clear seasonal trend was seen in results, it is recommended that sampling frequency be kept at monthly.

Depth of sampling

Not applicable

Tolerance

A standard sampling tolerance of 20 metres is recommended as this is a fixed aquaculture fishery.

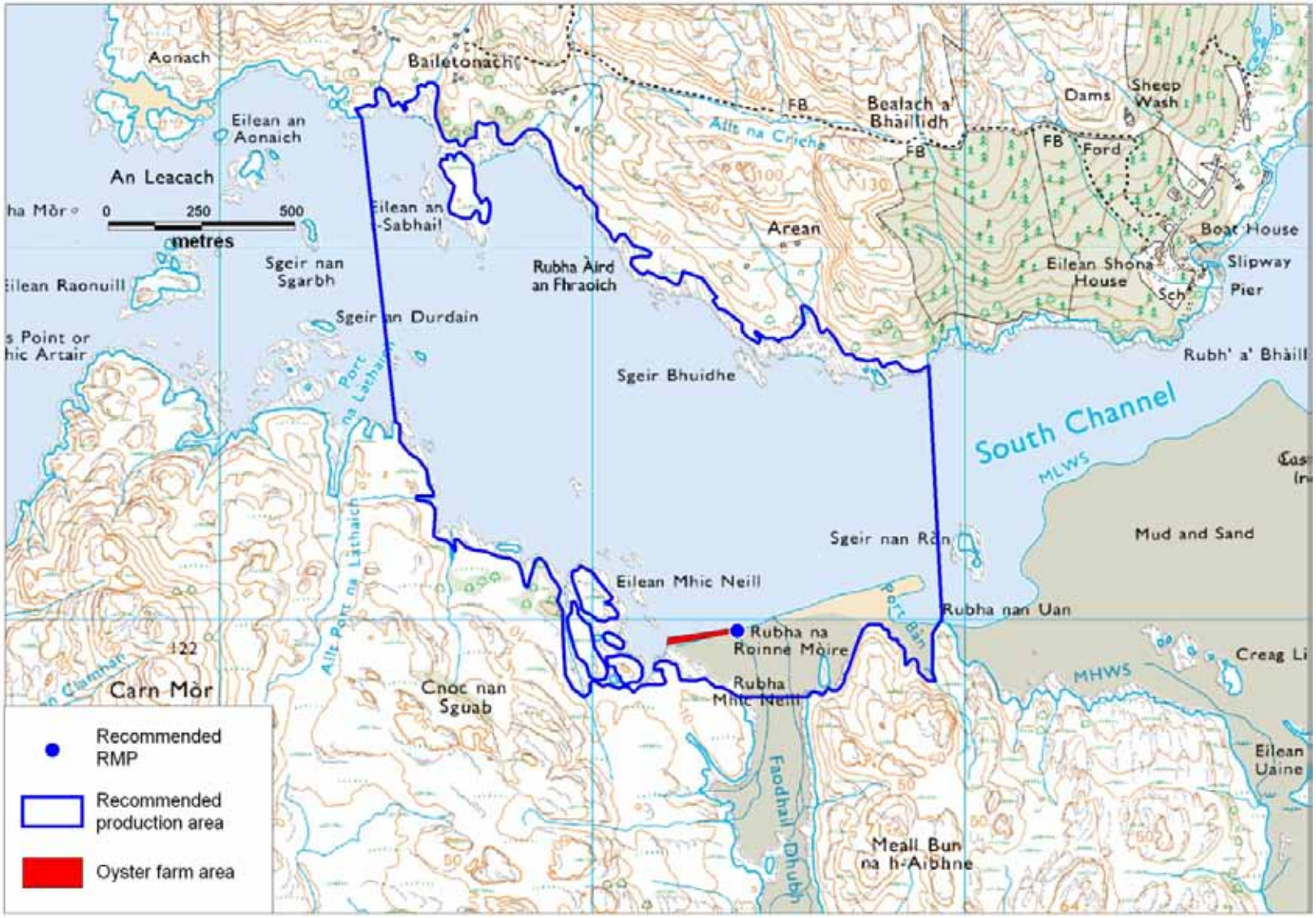

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Figure 17.1 Map of recommendations at Loch Moidart

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3. **Tables of Typical Faecal Bacteria Concentrations**
4. **Statistical Data**
5. **Hydrographic Methods**
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Geology and Soils Assessment Method

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 its 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

As mammals, whales and dolphins would be expected to have resident populations of *E. coli* and other faecal indicator bacteria in the gut. Little is known about the concentration of indicator bacteria in whale or dolphin

faeces, in large part because the animals are widely dispersed and sample collection difficult.

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

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

Birds

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

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

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

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

Deer

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, which may be washed into the water during periods of rain.

References:

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

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

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

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

Tables of Typical Faecal Bacteria Concentrations

Summary of faecal coliform concentrations (cfu 100ml-1) for different treatment levels and individual types of sewage-related effluents under different flow conditions: geometric means (GMs), 95% confidence intervals (Cis), and results of t-tests comparing base- and high-flow GMs for each group and type.

Indicator organism	Base-flow conditions				High-flow conditions			
Treatment levels and specific types: Faecal coliforms	n^c	Geometric mean	Lower 95% CI	Upper 95% CI	n^c	Geometric mean	Lower 95% CI	Upper 95% CI
Untreated	252	$1.7 \times 10^{7*}$ (+)	1.4×10^7	2.0×10^7	282	$2.8 \times 10^{6*}$ (-)	2.3×10^6	3.2×10^6
Crude sewage discharges	252	$1.7 \times 10^{7*}$ (+)	1.4×10^7	2.0×10^7	79	$3.5 \times 10^{6*}$ (-)	2.6×10^6	4.7×10^6
Storm sewage overflows					203	2.5×10^6	2.0×10^6	2.9×10^6
Primary	127	$1.0 \times 10^{7*}$ (+)	8.4×10^6	1.3×10^7	14	4.6×10^6 (-)	2.1×10^6	1.0×10^7
Primary settled sewage	60	1.8×10^7	1.4×10^7	2.1×10^7	8	5.7×10^6		
Stored settled sewage	25	5.6×10^6	3.2×10^6	9.7×10^6	1	8.0×10^5		
Settled septic tank	42	7.2×10^6	4.4×10^6	1.1×10^7	5	4.8×10^6		
Secondary	864	$3.3 \times 10^{5*}$ (-)	2.9×10^5	3.7×10^5	184	$5.0 \times 10^{5*}$ (+)	3.7×10^5	6.8×10^5
Trickling filter	477	4.3×10^5	3.6×10^5	5.0×10^5	76	5.5×10^5	3.8×10^5	8.0×10^5
Activated sludge	261	$2.8 \times 10^{5*}$ (-)	2.2×10^5	3.5×10^5	93	$5.1 \times 10^{5*}$ (+)	3.1×10^5	8.5×10^5
Oxidation ditch	35	2.0×10^5	1.1×10^5	3.7×10^5	5	5.6×10^5		
Trickling/sand filter	11	2.1×10^5	9.0×10^4	6.0×10^5	8	1.3×10^5		
Rotating biological contactor	80	1.6×10^5	1.1×10^5	2.3×10^5	2	6.7×10^5		
Tertiary	179	1.3×10^3	7.5×10^2	2.2×10^3	8	9.1×10^2		
Reed bed/grass plot	71	1.3×10^4	5.4×10^3	3.4×10^4	2	1.5×10^4		
Ultraviolet disinfection	108	2.8×10^2	1.7×10^2	4.4×10^2	6	3.6×10^2		

Source: Kay, 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: Log E.coli versus Season

```
Source  DF      SS     MS     F      P
Season   3  10.885  3.628  9.28  0.000
Error   43  16.808  0.391
Total   46  27.693

S = 0.6252   R-Sq = 39.31%   R-Sq(adj) = 35.07%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level    N    Mean   StDev  ------+---------+---------+---------+---
autumn   9  2.5054  0.8432                   (-------*--------)
spring  16  1.7374  0.5311      (------*-----)
summer  13  2.7445  0.5664                          (------*------)
winter   9  1.6302  0.6162  (--------*-------)
                           ------+---------+---------+---------+---
                               1.50      2.00      2.50      3.00

Pooled StDev = 0.6252


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

Individual confidence level = 98.94%


Season = autumn subtracted from:

Season    Lower   Center    Upper  --------+---------+---------+---------+-
spring  -1.4643  -0.7680  -0.0717     (------*------)
summer  -0.4855   0.2391   0.9637                (------*-------)
winter  -1.6630  -0.8753  -0.0875   (-------*-------)
                                  --------+---------+---------+---------+-
                                       -1.0       0.0       1.0       2.0


Season = spring subtracted from:

Season    Lower   Center   Upper  --------+---------+---------+---------+-
summer   0.3831   1.0071  1.6311                        (-----*-----)
winter  -0.8036  -0.1073  0.5890            (------*------)
                                  --------+---------+---------+---------+-
                                      -1.0       0.0       1.0       2.0


Season = summer subtracted from:

Season    Lower   Center    Upper  --------+---------+---------+---------+-
winter  -1.8390  -1.1144  -0.3897  (------*------)
                                  --------+---------+---------+---------+-
                                       -1.0       0.0       1.0       2.0
```

Hydrographic Methods

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

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

Background processes

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

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

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

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

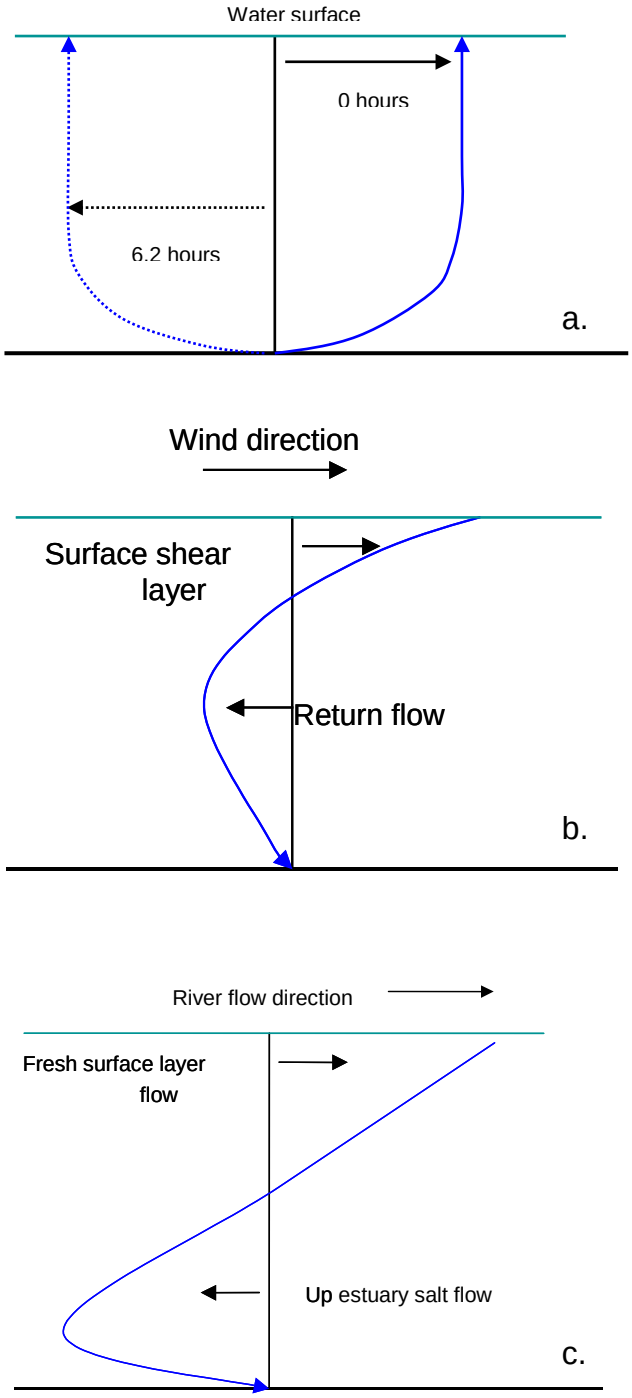

Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

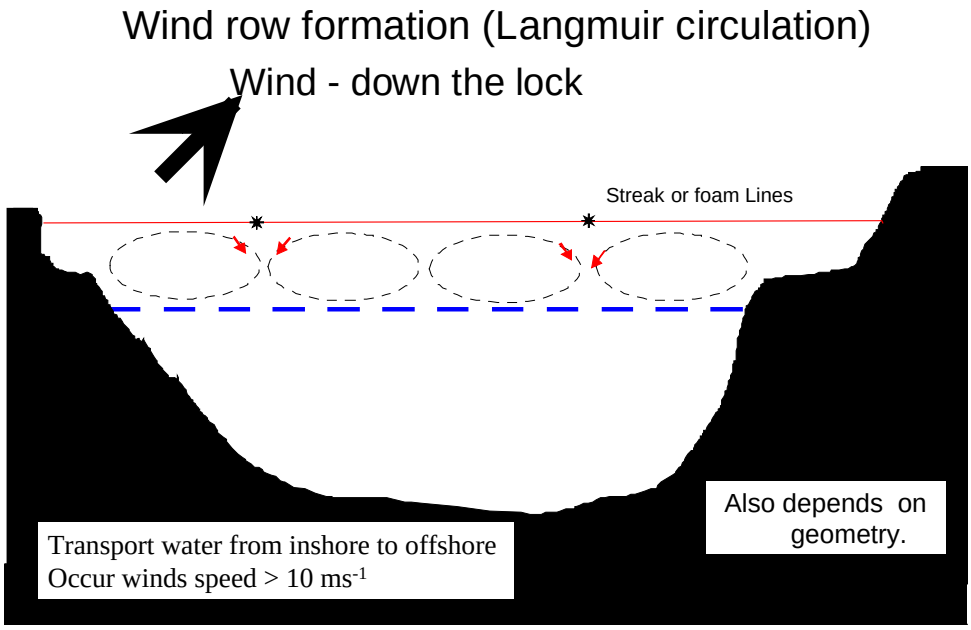

Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Non-modelling Assessment

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

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

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

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

generally have a surface layer of fresher water; the extent of this depends on freshwater input, sill depth and quantity of mixing.

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

References

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

Glossary

The following technical terms may appear in the hydrographic assessment.

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

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

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

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

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

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

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

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

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

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

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

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

Shoreline Survey Report

Prod. area:	Loch Moidart
Site name:	South Channel (HL 179 227 13)
Species:	Pacific oyster
Harvester:	Bill McDermott
Local Authority:	Highland Lochaber
Status:	Existing
Date Surveyed:	5-6th July 2011
Surveyed by:	Michelle Price-Hayward, Stephen Lewis, Charlotte Teague
Nominal RMP:	Sample point at fishery surveyed, NM 6427 7189
Area Surveyed:	Newton of Ardtoe to the head of Faodhail Dhubh, shoreline along mouth of River Shiel

Weather observations

5th July: Cloudy, rain showers. 15ºC, winds SW F4, gusting to F5. Weather dry for previous 3 days.

6th July: Cloudy. Heavy rain at times, otherwise showers. 17 ºC, winds light and variable.

Site Observations

Fishery

Pacific oysters are grown in triangular bags suspended from ropes set at approximately one meter above the seabed and at or just below MLWS. A dedicated line was set in place for sampling purposes that held two baskets of oysters. This was set higher up the shore and was accessible at any spring tide.

There was little to no stock available on the lines, as the harvester was in the process of clearing out to move production offshore. Rafts are to be put in place in the near future, from which the triangular bags will be suspended. Harvesting may occur at any time of year.

Sewage/Faecal Sources

A small number of homes were present at Newton of Ardtoe, to the south of the fishery. The majority of these were holiday lets. There were two homes in permanent occupation. A cabin was observed on the eastern shore, opposite the oyster farm. It had a septic tank, and the guttering around the roof appeared to be connected into black water pipe leading to the tank. A discharge pipe was observed just above the shoreline. This cabin was used by the harvester as an occasional base and holiday accommodation.

One septic tank was observed, and a large corrugated pipe exited the bank below the tank. This tank may have served two premises, as there was an inspection pipe at the property line between the two and appeared to be on a line from the adjacent property to the tank.

A small number of properties were observed along the east shore of the river. Many of these were reported by the sampling officer to be in seasonal occupation.

Farming and livestock

Livestock were present at the head of the Newton of Ardtoe, with both sheep and cattle found along streams or on the shoreline. At the farm, 12 cattle were observed in two fields on either side of the road. To the east, a stream, barely flowing at the time, passed through the pasture in which 6 cattle were kept and this was heavily poached near the edge of the field. There was a shed for winter housing a little way north along the road, and a muck-spreader was parked outside. Presumably this would be used to transport faecal wastes from livestock housing to on-farm storage or spreading on land. However, this is reportedly left parked near to one of the streams discharging to the embayment, where faecal waste is washed into the stream with rainfall.

Though 5 sheep were observed on the shoreline, the sampling officer identified that there were usually around 30-40 sheep in the flock and so the remainder may have been grazing further afield or out of the view of the observers. More of the flock was seen on the second day, though they were running away from the observers and could not be accurately counted. Sheep droppings were observed in the strand line and on the intertidal shore south of the fishery, particularly along the eastern shoreline of Faodhail Dhubh.

Seasonal Population

Many of the homes or caravans in the area are in seasonal occupation. There are two hotels at Acharacle, further upstream along the River Shiel. There are hotels and other guest accommodation at Acharacle, which lies further up the River Sheil. The village is served by a Scottish Water WWTW, which was observed. The discharge is to the river, though the pipe was not located.

Boats/Shipping

There were small workboats present on moorings around the area, and one yacht on a mooring just offshore of the oyster farm.

Land Use

Land along the western shoreline of Faodhail Dhubh, near the fishery, is primarily a mixture of open grass and heath with rocky outcrops. There is a farm at the head of the inlet at Newton of Ardtoe, where both cattle and sheep are kept. The eastern shore, as well as the shore of Eilean Shona is wooded. Along the River Shiel, where it meets Loch Moidart, the land to the west of the river is open whilst that east of the river is more wooded. Further along the river are more homes and woods.

Watercourses

Owing to the dry weather, many of the watercourses identified on the OS map were not flowing during the survey. The main burn discharging near the fishery was flowing at a low level. This was largely saline across much of the intertidal area, not dropping to below 10 ppt until near the very head of the inlet. This was measured and sampled.

On a revisit during the rainier second survey day another of the streams was observed to be flowing and this was measured and sampled. In addition, the permanent stream was remeasured and resampled.

Other small streams were found along the outer shores of the River Shiel. The river was measured and sampled from the old bridge upriver from the loch.

Wildlife/Birds

Wading birds, gulls and wild geese were observed in Loch Moidart, and one pair of oystercatchers were observed south of the fishery. Otherwise, no other significant aggregations of birds were observed. No deer were directly observed near the fishery, however there was a butcher specialising in venison in the area, suggesting that there might be large numbers of deer around.

The sampling officer reported having seen both seals and otters in and around the area, though none were seen during the survey.

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 loch.

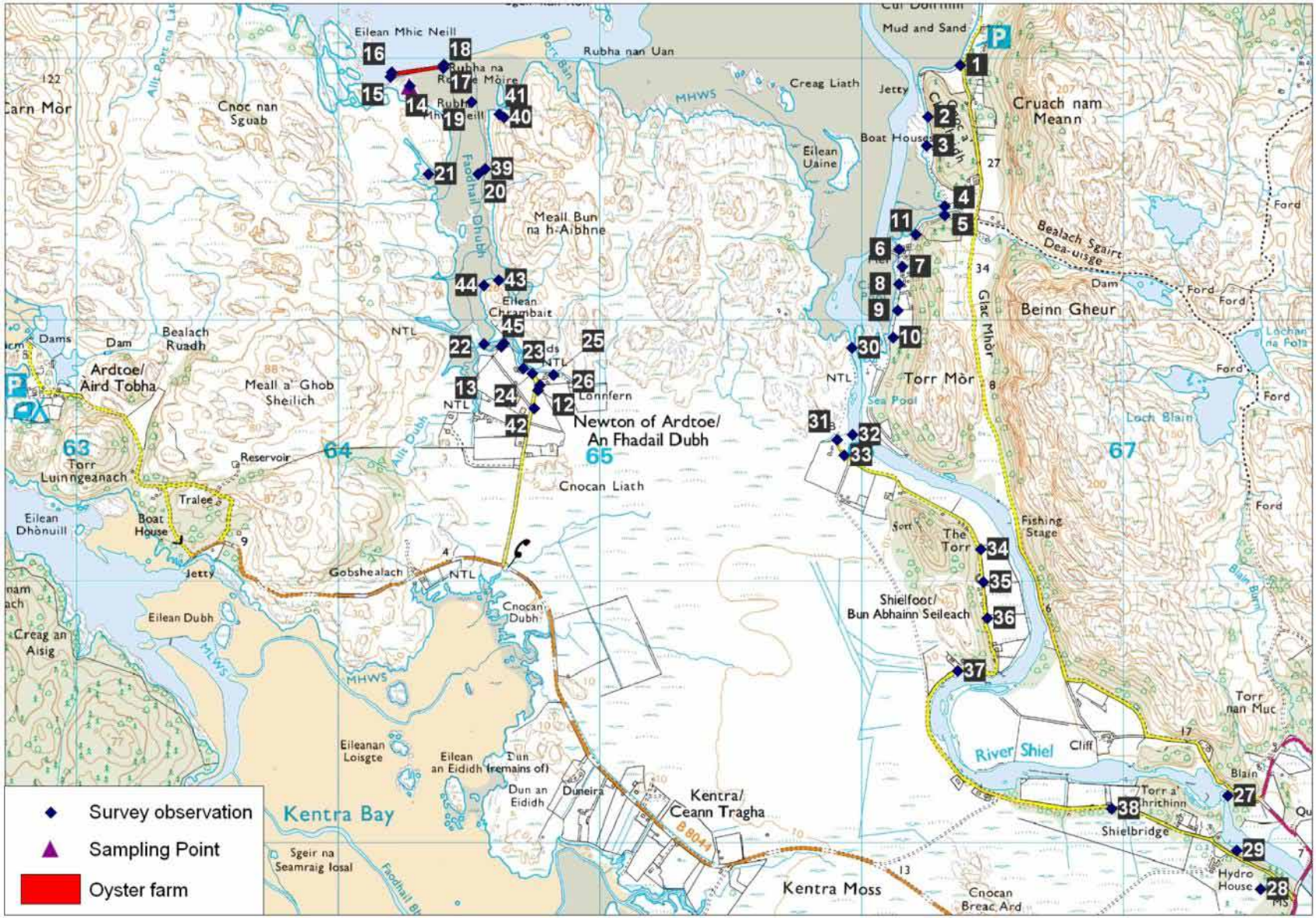

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Figure 1. Map of Shoreline Observations

Table 1. Shoreline Observations

No.	Date	Time (GMT)	NGR	East	North	Associated photograph	Description
1	05-07-2011	10:50	NM 6638 7198	166380	771980	Figure 4	Very small stream, barely trickling. Not measured or sampled (too little flow)
2	05-07-2011	10:59	NM6625 7178	166250	771780		Sheep in view on Eilean Uaine – 6 visible, more likely to be hidden by terrain Large number of shore birds – 40-50 oystercatchers, 12 geese, 20-30 gulls
3	05-07-2011	11:13	NM 6625 7167	166250	771670		Boat shed
4	05-07-2011	11:21	NM 6632 7144	166320	771440		Stream, 35cm x 5cm, flow 0.247 m/s Water sample 1
5	05-07-2011	11:36	NM 6632 7140	166320	771400	Figure 5	Stream, runs from a pond, past an empty shack, 95cm x 4cm, flow 0.269 m/s. Water sample 2
6	05-07-2011	11:50	NM 6614 7127	166140	771270	Figures 6, 7	House, 3 small moorings, 2 angling boats, 1 open boat, slipway.
7	05-07-2011	11:55	NM 6616 7120	166160	771200		Two houses, 8 chickens, 2 geese.
8	05-07-2011	11:56	NM 6614 7114	166140	771140	Figure 8	Septic tank, 2 houses. Tide line comes right up to the tank; a larger spring tide would inundate the tank. Water sample 3 (seawater)
9	05-07-2011	12:03	NM 6614 7104	166140	771040		Dry stream bed
10	05-07-2011	12:06	NM 6612 7093	166120	770930	Figure 9	House, small septic tank, holiday let.
11	05-07-2011	12:14	NM 6621 7133	166210	771330	Figure 10	Pipe offshore roughly 30m from road, at least 1 meter deep, not flowing, possibly running from house. 13 sheep
12	05-07-2011	14:09	NM 6476 7073	164760	770730	Figure 11	12 Cattle on farm, 6 either side of the road. A ditch/stream flowing through one side, heavily poached by livestock.
13	05-07-2011	14:16	NM 6463 7091	164630	770910		5 sheep along main stream discharging to Ardtoe
14	05-07-2011	14:58	NM 6427 7190	164270	771900	Figure 12	Sampling bags. Water sample 4 (seawater), shellfish sample 1
15	05-07-2011	15:24	NM 6420 7193	164200	771930		Corner of oyster farm
16	05-07-2011	15:25	NM 6420 7195	164200	771950		Corner of oyster farm
17	05-07-2011	15:31	NM 6440 7198	164400	771980		Corner of oyster farm
18	05-07-2011	15:32	NM 6440 7197	164400	771970		Corner of oyster farm
19	05-07-2011	15:49	NM 6451 7184	164510	771840	Figure 13	Shellfish sample 2 – shore mussels taken from centre of bay.
20	05-07-2011	16:11	NM 6453 7156	164530	771560		Stream channel running across shore – 4.3m x 8cm, flow 0.225 m/s salinity 25 ppt. No sample
21	05-07-2011	16:17	NM 6434 7156	164340	771560	Figure 14	Stream barely flowing, insufficient to measure or sample. Some *Beggiatoa* apparent
22	05-07-2011	16:36	NM 6456 7091	164560	770910	Figure 15	Main burn, further up shore, 2m wide x 5cm 0.036 m/s. Water sample 5.
23	05-07-2011	16:46	NM 6471 7081	164710	770810		Septic tank outfall from holiday cottage, dry. Corrugated plastic pipe 30cm diameter. Tank in garden above
24	05-07-2011	16:50	NM 6474 7080	164740	770800	Figure 16	Caravan on adjacent property, inspection port at property line suggests both properties on same tank. Small discharge pipe below caravan, Green corrugated plastic, 10cm diameter,
25	05-07-2011	16:57	NM 6482 7079	164820	770790		Septic tank next to caravan. No obvious outlet. Stagnant stream with red bacterial film.
26	05-07-2011	17:01	NM 6477 7075	164770	770750		Poached ground,, cattle droppings

No.	Date	Time (GMT)	NGR	East	North	Associated photograph	Description
27	06-07-2011	11:47	NM 6740 6918	167400	769180	Figure 17	River Shiel, at old road bridge. 6.5m x 2.7m. Flow estimated using float timings under the bridge over a distance of 4.7m (15s, 13s, 13s.) Calculated flow 0.34 m/s. Water sample 6.
28	06-07-2011	12:48	NM 6753 6882	167530	768820		Acharacle WWTW.
29	06-07-2011	13:23	NM 6744 6897	167440	768970		End of a drainage pipe, no flow apparent at time
30	06-07-2011	14:01	NM 6596 7089	165960	770890		Rapids
31	06-07-2011	14:24	NM 6591 7054	165910	770540		6 houses, 3 caravans
32	06-07-2011	14:33	NM 6597 7056	165970	770560		Water sample 7, River Shiel
33	06-07-2011	14:43	NM 6594 7048	165940	770480		Garden with polytunnel, 2 geese, chickens, approximately 30 sheep, area poached, most sheep fenced away from river, however sheep droppings found all along bank.
34	06-07-2011	14:51	NM 6646 7012	166460	770120		3 houses, 2 sheep, chickens
35	06-07-2011	14:53	NM 6647 6999	166470	769990		Organic vegetable farm, 10 sheep in field adjacent to river, 2 houses
36	06-07-2011	14:54	NM6648 6986	166480	769860		3 houses
37	06-07-2011	14:55	NM 6637 6966	166370	769660		1 house
38	06-07-2011	14:57	NM 6696 6913	166960	769130		2 houses
39	06-07-2011	15:27	NM 6456 7158	164560	771580		Large concentration of shells: cockles, clams, native oyster, auger shells, winkles, mussels further to north.
40	06-07-2011	15:37	NM 6463 7178	164630	771780	Figure 18	Cabin, gutter drain appears to join toilet drain from under cabin, pipe runs to a septic tank approx. 30m away. No one in cabin – harvester at work on site.
41	06-07-2011	15:42	NM 6462 7179	164620	771790	Figure 19	Septic pipe, dribbling lightly
42	06-07-2011	16:41	NM 6475 7066	164750	770660		Livestock barn and slurry spreader
43	06-07-2011	17:06	NM 6461 7115	164610	771150		Stream, salinity 7 ppt. 183cm x 4.5cm, flow 0.093m/s, water sample 8
44	06-07-2011	17:14	NM 6456 7113	164560	771130		Sheep droppings on shore and in tide line
45	06-07-2011	17:20	NM 6462 7090	164620	770900		Stream, salinity 4ppt, 2.5m x 4cm, flow 0.141m/s, water sample 9.

Photographs referenced in the table can be found attached as Figures 4-19.

Sampling

Water and shellfish samples were collected at sites marked on the map. Where indicated in Table 1, salinity was recorded in the field using a refractometer. Samples were transferred to a Biotherm 25 box with ice packs and shipped to Glasgow Scientific Services on 11th August for *E. coli* analysis. Samples were received by the laboratory on 13th August. The sample temperature on arrival was 7.5˚C, which was within the recommended temperature range of 2-8˚C. The National Reference Laboratory (NRL) undertook a study on the effect of temperature and time of storage on levels of *E. coli* in shellfish and found no significant effect with up to 48 hours' storage at temperatures ≤10ºC. These results have been included in Tables 2 and 3.

Seawater samples were tested for salinity by the laboratory and results reported in mg Chloride per litre. These results have been converted to parts per thousand (ppt), and are shown in Table 2.

Table 2. Water Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (cfu/100 ml)	Salinity (ppt)
1	05/07/11	LM01	NM 6632 7144	Freshwater	<100	na
2	05/07/11	LM02	NM 6632 7140	Freshwater	<100	na
3	05/07/11	LM03	NM 6614 7114	Seawater	2900	22.3
4	05/07/11	LM04	NM 6427 7190	Seawater	100	35.2
5	05/07/11	LM05	NM 6456 7091	Freshwater	800	na
6	06/07/11	LM06	NM 6740 6918	Freshwater	200	na
7	06/07/11	LM07	NM 6597 7056	Freshwater	800	na
8	06/07/11	LM08	NM 6461 7115	Freshwater	1000	na
9	06/07/11	LM09	NM 6462 7090	Freshwater	7400	na

It should be noted that water samples 1 through 5 were taken after several consecutive days of dry weather and that heavy rain fell overnight and during the day when samples 6-9 were taken.

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (MPN/100 g)
1	05/07/11	LM shellfish 1	NM 6427 7190	Pacific oyster	80
2	05/07/11	SM shellfish 2	NM 6451 7184	Common Mussel	110

Both shellfish samples were taken after a period of dry weather.

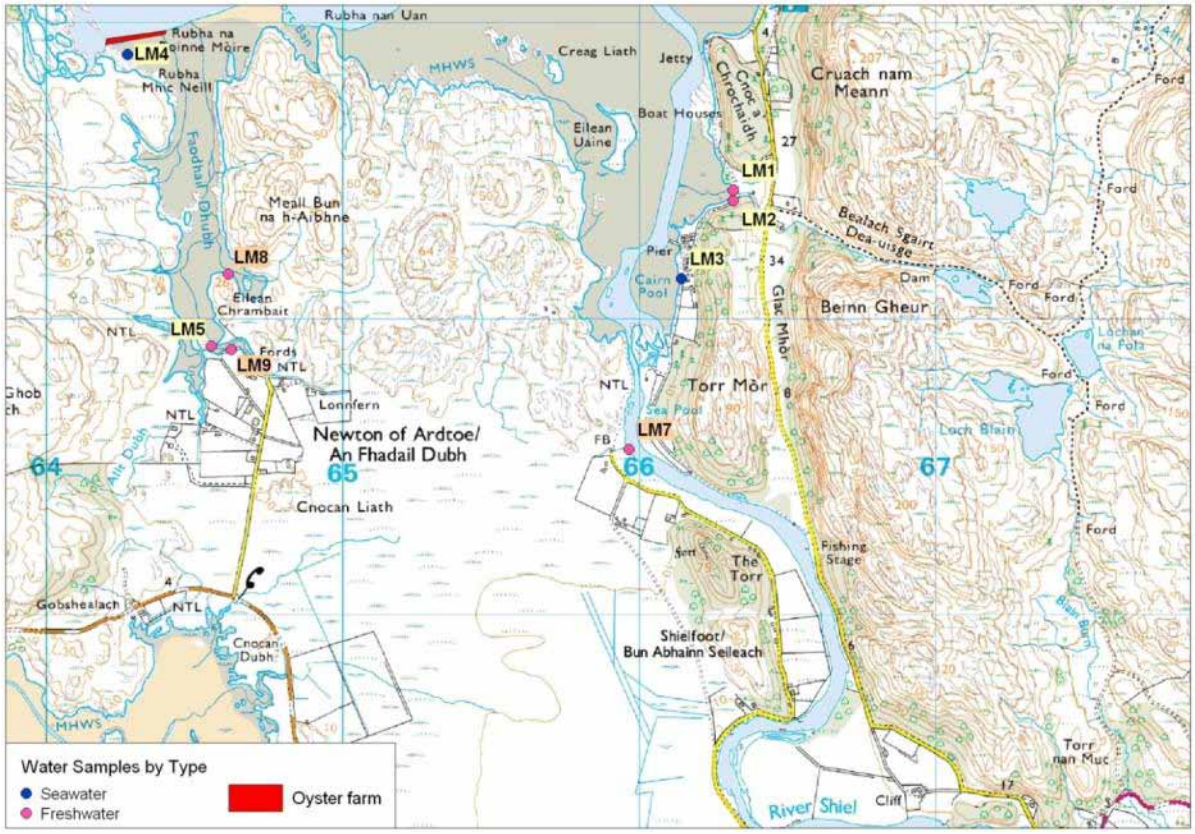

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Figure 2. Water sample results map

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Figure 3. Shellfish sample results map

Photographs

Figure 4. Small stream

Figure 5. Stream

Figure 6. Angling boats on moorings

Figure 7. Small open boat and slipway

Figure 8. Septic tank near high tide mark

Figure 9. Small cottage with septic tank in garden

Figure 10. Unidentified pipe

Figure 11. Cattle at Newton of Ardtoe

Figure 12. Sampling point

Figure 13. Collecting mussel sample from bay

Figure 14. Channel with drainage and some runoff

Figure 15. Main burn channel

Figure 16. Drainage pipe below septic tank

Figure 17. Sample point at old bridge, River Shiel

Figure 18. Septic tank below walkway

Figure 19. Outfall pipe from septic tank