Scottish Sanitary Survey Project

Sanitary Survey Report
Loch Ailort (HL 114)
July 2010

Report Distribution – Loch Ailort

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

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1. General Description

Loch Ailort is an enclosed sea loch located on the west coast of the Highlands. The majority of the loch is enclosed and therefore fairly sheltered. The loch is 7.4 km in length, 0.5 km at its narrowest and 1.8 km at its widest point. The eastern end of the loch reaches depths up to 50 m whilst the western end of the loch only reaches depths of up to 20 m. This sanitary survey was undertaken to coincide with an FSAS funded norovirus study carried out throughout 2009.

Figure 1.1 Location of Loch Ailort

2. Fishery

The fishery at Loch Ailort consists of two active longline mussel farms, with a further mussel farm currently under construction. In addition, Pacific oysters are cultured on trestles in the intertidal zone at the head of the loch. Details of these active sites are presented in Table 2.1. FSAS classification records list several other site/species combinations within this production area. These are no longer active so are only given further consideration in this report in relation to their historic *E. coli* monitoring results.

The outer part of Loch Ailort comprises part of the Sound of Arisaig marine Special Area of Conservation (mSAC). This mSAC therefore covers the three mid-loch seabed lease areas at Site 1 – Muckairn mussels and Eilean Buidhe. However, although intensive shellfish farming may cause damage important maerl habitat, the mSAC management plan document (Highland Council, 2000) acknowledges that there is potential for further development of shellfish farming in Loch Ailort. Continued use of current shellfish farm leases has been accepted, and further development may be considered, providing it is consistent with the conservation objectives. Relevant authorities will be reviewing leases when applications are made for renewal.

Table 2.1 Active shellfish sites within Loch Ailort

Production Area	Site	SIN	Species
Loch Ailort	Camus Driseach	HL 114 207 13	Pacific oyster
Loch Ailort	Site 1 – Muckairn mussels	HL 114 214 08	Common mussel
Loch Ailort	Eilean Dubh	HL 114 937 08	Common mussel
Loch Ailort	Eilean Buidhe	HL 114 209 08	Common mussel

The Loch Ailort production area boundaries are given as "a line drawn between NM 6800 7825 and NM 6912 8069 extending to mean high water springs (MHWS)". This covers the entire loch. Representative monitoring points (RMPs) are located at NM 750 822 for mussels and at NM 763 816 for Pacific oysters.

Pacific oysters at Camus Driseach

Pacific oysters are cultured on trestles in the intertidal zone at the head of the loch, where they take about 5-7 years to reach harvest. A range of sizes were present at the time of survey, including stock of a marketable size. Harvesting may occur at any time of the year, and the oysters are sold on to a wholesaler. Native oysters were also harvested from here until recently.

Mussels at Site 1 – Muckairn mussels

This consists of three lines each of about 200 m in length from which 8 m droppers are suspended. Mussels take about 3 years to grow to a marketable size. Harvesting was imminent at this site at the time of survey.

Mussels at Eilean Dubh
This site consists of two 300 m long lines, one with extension of a further 100 m from which 5 m droppers are suspended. Stock of a range of sizes was present at the time of the survey, including stock approaching a harvestable size. Harvesting can occur at any time of the year, with the next harvest scheduled for 2010.

Mussels at Eilean Buidhe
A single line of floats about 200m in length has been deployed here, and at the time of survey no droppers were attached. It is planned that droppers be attached to collect the next spatfall (spring 2010). This site is under the same ownership as Site 1 – Muckairn mussels.

Figure 2.1 shows an overview of the relative positions of the shellfisheries, Food Standard Agency Scotland designated production area, Crown Estates lease area and RMPs. More detailed views of the fisheries in the mid and upper loch are shown in Figures 2.2 and 2.3 respectively.

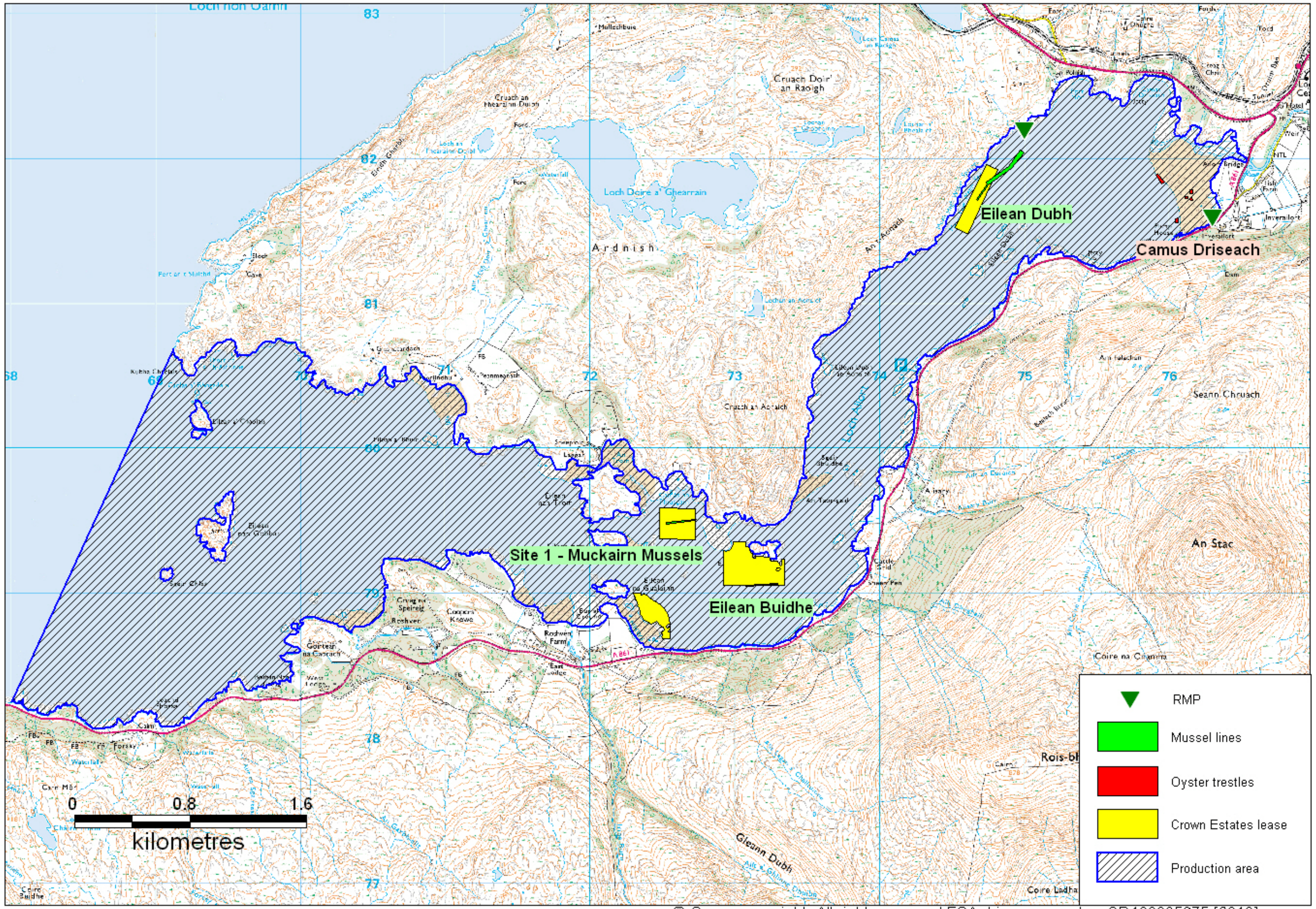

Figure 2.1 Loch Ailort Fisheries

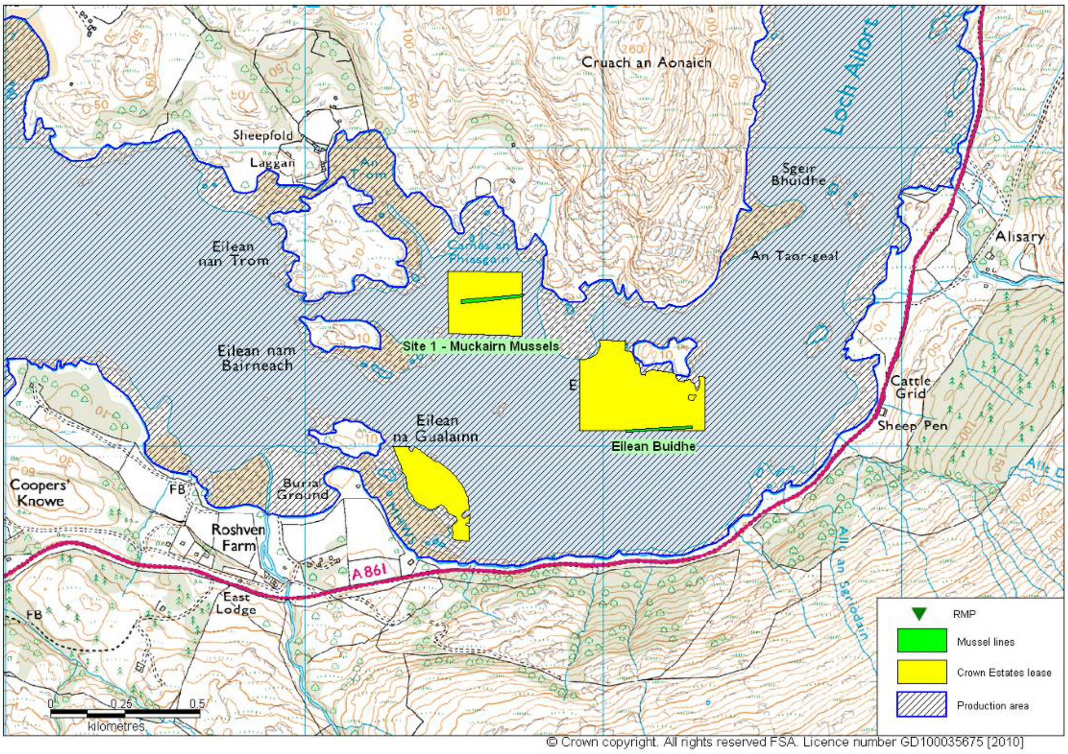

Figure 2.2 Loch Ailort Fisheries – mid loch

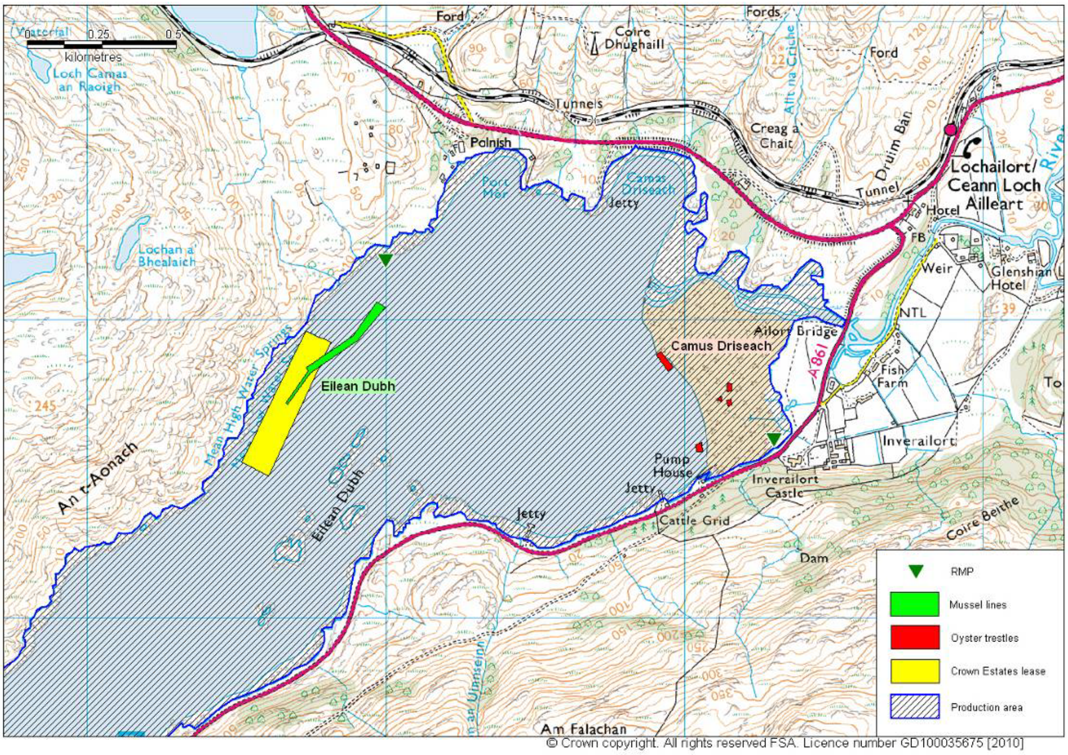

Figure 2.3 Loch Ailort Fisheries – upper loch

3. Human Population

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

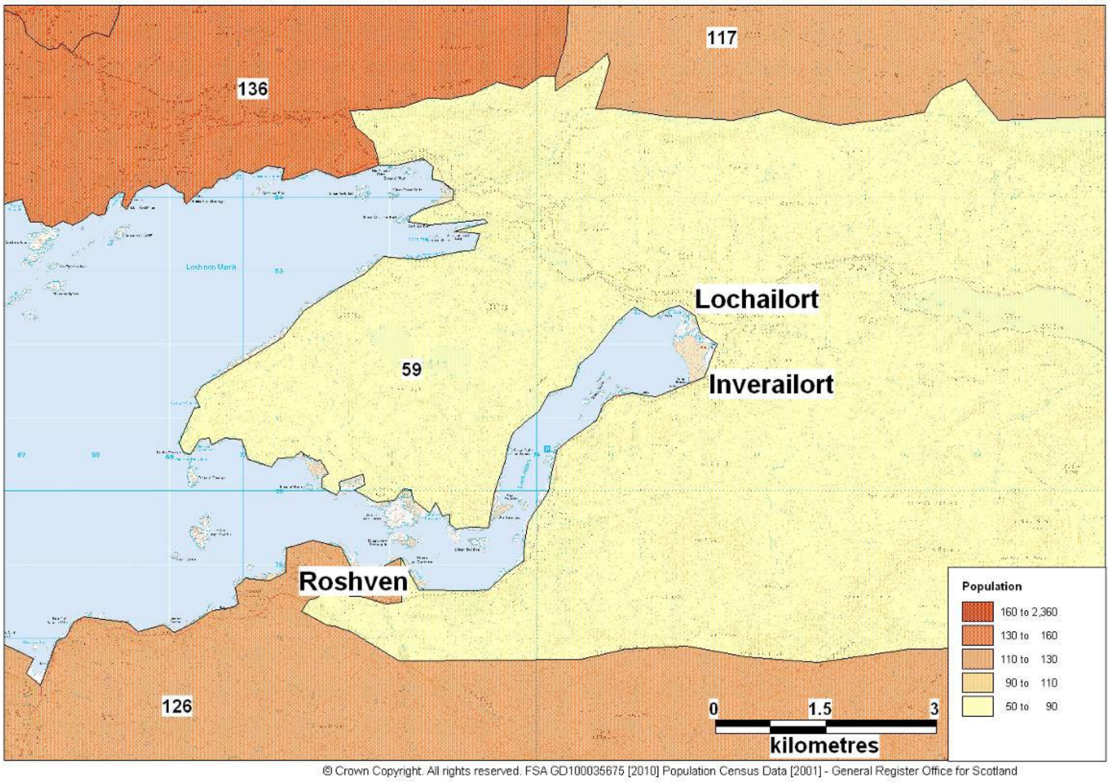

Figure 3.1 Human population surrounding Loch Ailort

The population census output area surrounding most of Loch Ailort has a population of 59. This includes the village of Lochailort (with Inverailort), which lies at the head of the loch. The combined population of the Lochailort/Inverailort area for 2007 was estimated at 28 (The Highland Council, 2008). On the outer southern shore of Loch Ailort is a census output area with a population of 126. This includes the small hamlet of Roshven. Only a small fraction of the population within this latter census area resides on the shores of Loch Ailort.

In conclusion, population on the shores of Loch Ailort is very low, and is centred around Loch Ailort at its head, and the smaller settlement of Roshven on the south shore of the outer loch.

4. Sewage Discharges

There are no Scottish water discharges to Loch Ailort. Eleven discharge consents have been issued by SEPA within the area shown in Figure 4.1, details of which are presented in Table 4.1.

Table 4.1 Discharges identified by SEPA

Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Consented/ design PE	Discharges to
CAR/R/1034444	NM 6994 7825	Domestic	Puraflo treatment unit	6	Unnamed Burn via partial soakaway
CAR/R/1037586	NM 7604 8140	Domestic	Septic tank	5	Unnamed watercourse
CAR/R/1016298	NM 7704 8280	Domestic	Septic tank	5	Allt Maodsil
CAR/R/1031470	NM 7188 7858	Domestic	Septic tank	5	Irine Burn
CAR/R/1022477	NM 7058 7877	Domestic	Puraflo treatment unit	15	Land via soakaway
CAR/R/1037862	NM 7031 7832	Domestic	Septic tank	6	Land via soakaway
CAR/R/1032391	NM 7862 8296	Domestic	Septic tank	5	Lochan Dubh
CAR/R/1031472	NM 7194 7859	Domestic	Septic tank	25	Land via soakaway
CAR/R/1018712	NM 7681 8226	Domestic	Septic tank	10	River Ailort
CAR/R/1016135	NM 6972 7831	Domestic	Package plant	6	An Garbh Allt
CAR/R/1013605	NM 7649 8158	Domestic	Septic tank	13	Unnamed Burn

These discharges all relate to small private domestic sewage treatment systems. Of these, three discharge to land via a soakaway, and therefore should have no impact on water quality in Loch Ailort if they are functioning correctly. The remainder discharge to watercourses feeding into Loch Ailort in two distinct clusters. At Roshven there are 3 discharges with a total population equivalent of 11, and at Lochailort/Inverailort there are 5 discharges with a total population equivalent of 38. Puraflo treatment units incorporate a settlement tank followed by filtration through peat, and are reported by the manufacturers to achieve a >99% (2-log) reduction in faecal coliforms. As there has not historically been a requirement to register septic systems in Scotland, this list is unlikely to cover all septic tanks in the area. A physical survey of the shoreline was undertaken and observations of septic tanks and/or outfalls present along the shoreline of Loch Ailort are presented in Table 4.2.

Table 4.2 Discharges and septic tanks observed during shoreline survey

No	Date	Position	Observation
1	03/11/2009	NM 76056 81695	10 cm diameter cast iron pipe to underwater.
2	04/11/2009	NM 76234 81569	12 cm cast iron pipe, points back towards the large house which hosts Lochailort Post Office, broken in places, clean looking water coming from the breaks
3	05/11/2009	NM 69715 78311	Septic tank or possibly package plant with outflow to stream, serves 1 house, not flowing
4	05/11/2009	NM 69775 78344	Septic tank with pipe to stream, dripping, serves one house
5	05/11/2009	NM 75483 81267	11 cm orange sewer pipe to shore from marine harvest building, dripping.

Two of these discharges are to the intertidal area at the head of the loch where the Camus Driseach oyster site is located. A seawater sample taken by the end of the pipe described in observation 1 contained 1600 *E. coli* cfu/100ml, suggesting it may have sewage content. A sample of water coming from one of the breaks in the pipe described in observation 2 contained >100,000 *E. coli* cfu/100ml indicating sewage content. It is believed that this discharge serves Inverailort Castle, and is untreated. About 700 m to the west, a septic tank discharge from the Marine Harvest building was recorded (observation 5).

Two small private septic tank/package plant discharges were observed at Roshven. Of these discharges, it is probable that observation 3 relates to SEPA consent CAR/R/1016135.

In summary, known discharges to the production area, or to watercourses draining into the production area are centred around Lochailort/Inverailort at the head of the loch, and Roshven on the south shore.

Boating traffic observed during the shoreline survey was limited to a few small craft. Seven dinghies and small yachts were recorded on moorings just to the east of Roshven. There was an active fish farm just off the south shore towards the head of the loch, with frequent small boat traffic between its land base on the adjacent shore and the cages. Two yachts and one RIB were seen on moorings in this area. It is likely that the yachts, when occupied, discharge overboard.

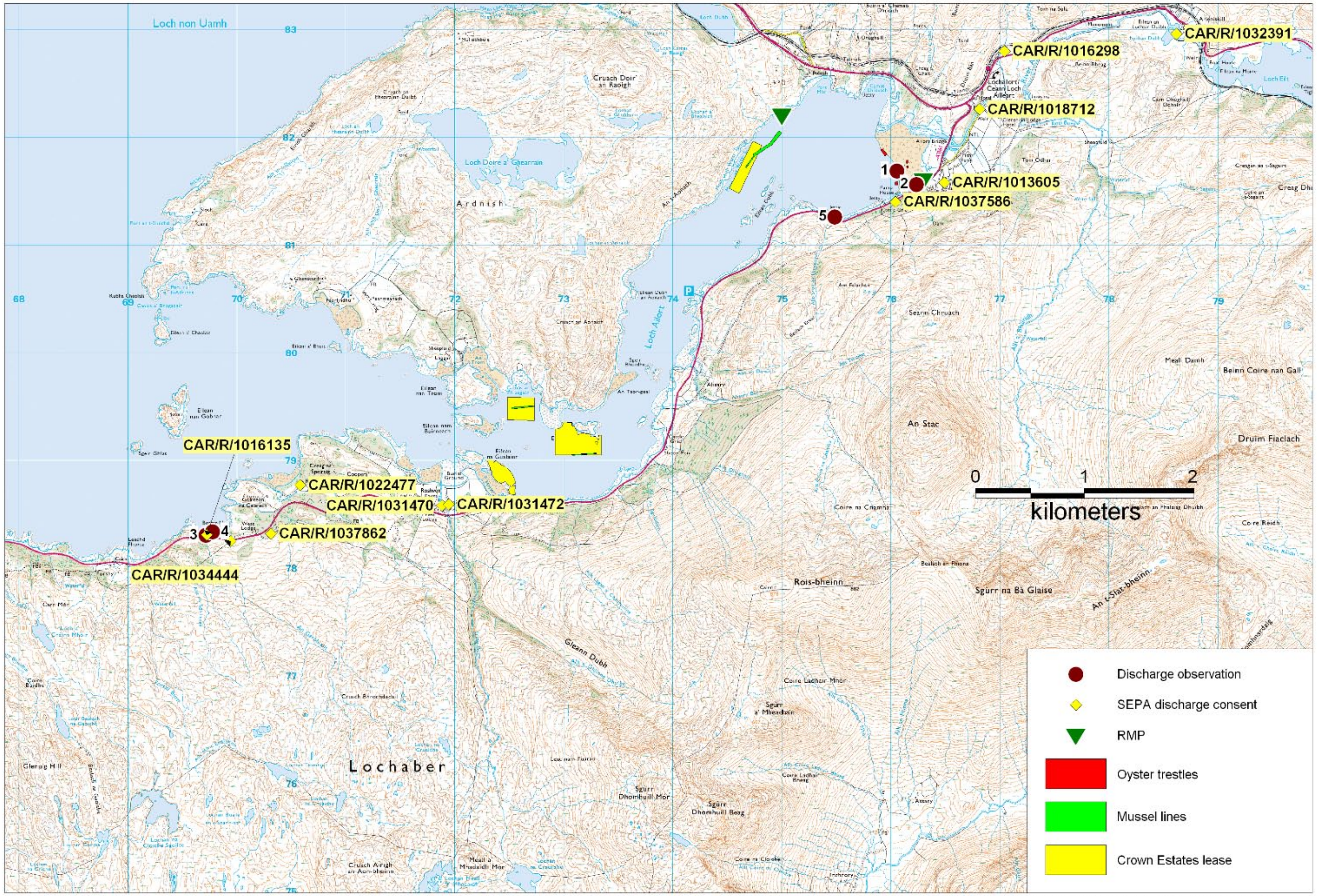

Figure 4.1 Sewage discharges at Loch Ailort

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, orange and yellow indicate poorly draining soils.

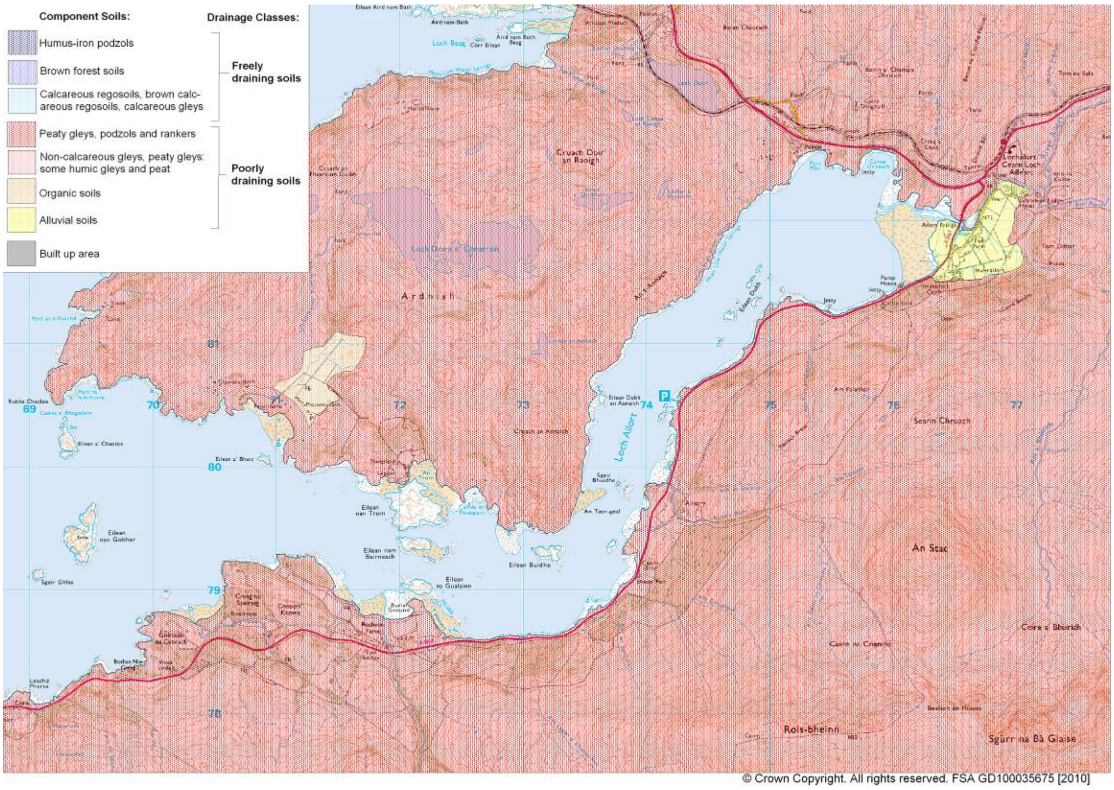

Figure 5.1 Component soils and drainage classes for Loch Ailort

Three types of component soils are present in the area: peaty gleys, podzols and rankers, organic soils and alluvial soils. All of these soils are poorly draining. Therefore, the potential for runoff contaminated with *E. coli* from human and/or animal waste is high for all the land surrounding Loch Ailort.

6. Land Cover

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

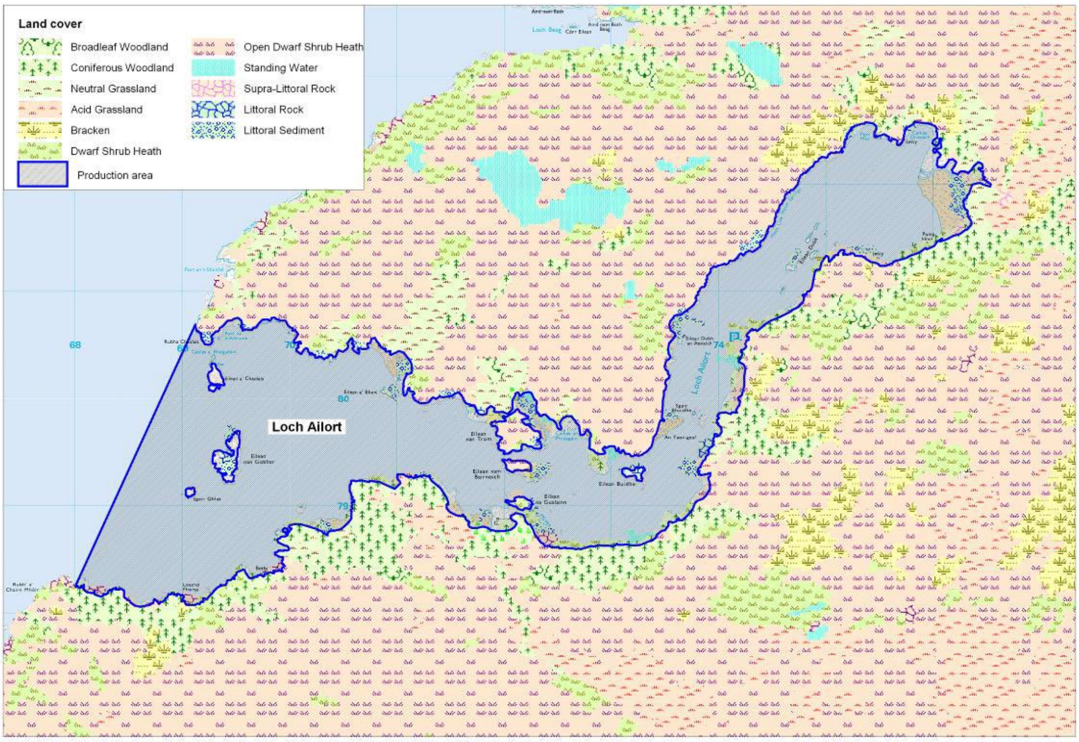

Figure 6.1 LCM2000 class land cover data for Loch Ailort

There are several different types of land cover shown in Figure 6.1 for the area surrounding Loch Ailort. The dominant land cover type is open dwarf shrub heath, which covers much of the land and is scattered with patches of coniferous woodland, bracken, acid grassland, neutral grassland and dwarf shrub heath. Along the southern side of Loch Ailort there are patches of mainly coniferous woodland but also broadleaf woodland, along the coastline.

No developed areas or improved grassland were identified in the area surrounding Loch Ailort. The faecal coliform contribution would be expected to be highest from developed areas (approx 1.2 – $2.8x10^9$ cfu km^{-2} hr^{-1}), with intermediate contributions from improved grassland (approximately $8.3x10^8$ cfu km^{-2} hr^{-1}) and lowest from other land cover types (approximately $2.5x10^8$ cfu km^{-2} hr^{-1}) (Kay *et al*. 2008). The contributions from all land cover types would be expected to increase significantly after marked rainfall events.

Therefore, the overall predicted contribution of contaminated runoff from the land cover types shown in the map would be low, but may increase significantly following rainfall events. The developed areas at Lochailort, Inverailort and Roshven are not shown on the map and would be expected to contribute significantly to contamination entering the loch.

7. Farm Animals

Agricultural census data was received from the Scottish Government Rural and Environment Research and Analysis Directorate (RERAD) for the Arisaig and Moidart parish, which surrounds Loch Ailort and covers an area of 464.3 km^2. Recorded livestock populations for the parishes for 2007 and 2008 are presented in Table 7.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reported would have made it possible to discern individual farm data.

Table 7.1 Livestock numbers in the Arisaig and Moidart Parish, 2007-8.

	2007		2008	
	Holdings	Numbers	Holdings	Numbers
Pigs	*	*	*	*
Poultry	17	4418	16	4269
Cattle	27	741	24	750
Sheep	23	2967	19	2531
Horses and Ponies	9	22	8	27
Other livestock	*	*	*	*

*Data withheld for confidentiality

Livestock kept within this parish is primarily a mixture of sheep and cattle at relatively low densities (5.5 sheep and 1.6 cattle per km^2 in 2008). There are also a number of poultry rearing operations within the parish. Due to large area of this parish, this data does not provide information on the livestock numbers in the area immediately surrounding the production areas. The only significant source of local information was therefore the shoreline survey (see Appendix), which only relates to the time of the site visit on 3rd-5th November 2009. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1. This information should be treated with caution, as it applies only to the survey dates and is dependent upon the point of view of the observer (some animals may have been obscured from view by the terrain).

Little was seen in the way of livestock during the shoreline survey. The largest aggregation of livestock was approximately 30 sheep in a field at Lochailort. At one point during the shoreline survey, these were seen on the salt grassland at the head of the loch, where they had access to the shore on which the oyster trestles are located. Several hours after this observation was made they had returned to their original field. The sampling officer reports regularly seeing sheep on the salt grassland, and sheep droppings were noted on this grassland during the shoreline survey. As parts of this grassland may be covered at high water on spring tides, this is likely to constitute a significant source of contamination for the Camus Driseach site, and may make a significant contribution to levels of contamination in the upper loch.

Four horses and a chicken shed were recorded at Roshven, and a group of nine sheep were recorded on the road on the south shore of the outer loch.

Numbers of sheep will approximately double during May following the birth of lambs, and decrease in the autumn as they are sent to market. It is likely that they will visit streams to drink and cool off more frequently during the warmer months so overall impact from livestock are likely to be higher from May to October.

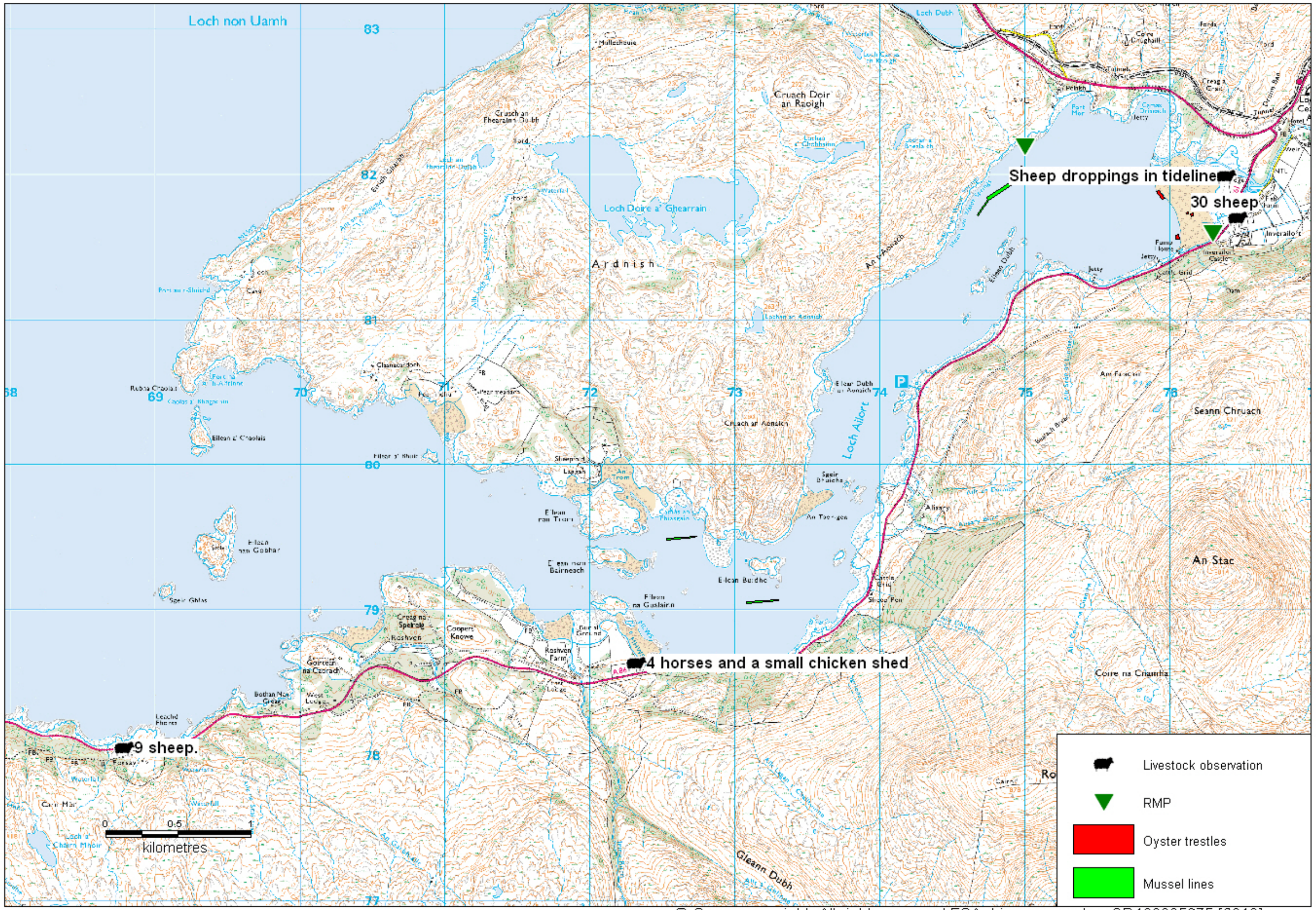

Figure 7.1 Shoreline survey livestock observations

8. Wildlife

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

Seals

Two species of pinniped (seals, sea lions, walruses) are commonly found around the coasts of Scotland: These are the European harbour, or common, seal (*Phoca vitulina vitulina*) and the grey seal (*Halichoerus grypus*). Scotland hosts significant populations of both species.

A survey conducted by the Sea Mammal Research Unit in 2005 estimated a population of 4966 common seals from Cape Wrath to Appin (Sea Mammal Research Unit, 2007). The exact locations of the haul out sites were not specified. Although there was no specific data on grey seals in Loch Ailort, small numbers have been recorded on the nearby islands of Rum and Muck, so it is likely that this species also frequent Loch Ailort from time to time.

Three adult seals and one pup (species uncertain) were recorded during the course of the shoreline survey, although these were all seen at different times and some may have been repeat sightings of the same animal.

Whales/Dolphins

A variety of whales and dolphins are routinely observed off the west coast of Scotland. However it is unlikely that cetaceans enter the loch due to the shallow depth at the entrance.

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. Although there is a significant population of red deer in the vicinity of Loch Ailort, no counts were undertaken here at the most recent census (2006). A total of four deer were seen during the shoreline survey. It is therefore likely that some of the indicator organisms detected in the streams feeding into the production area will be of deer origin, although their contribution relative to other sources is not known.

Birds

A number of bird species are found around Loch Ailort, but seabirds and waterfowl are most likely to occur around or near the fisheries. A number of seabird species breed in Lochaber. These were the subject of a detailed census carried out in the late spring of 1999 and 2000 (Mitchell *et al.*, 2004).

Total counts of all species recorded within 5 km of the production areas are presented in Table 8.1. Where counts were of sites/nests/territories occupied by breeding pairs actual numbers of birds breeding in the area will be higher.

Table 8.1 Counts of breeding seabirds within 5 km of the production area

Common name	Species	Count	Method	Individual/ Pair
Herring gull	*Larus argentatus*	110	Occupied nests	pairs
Common gull	*Larus canus*	24	Occupied nests	pairs
Great black-backed gull	*Larus marinus*	13	Occupied nests	pairs
European shag	*Phalacrocorax aristotelis*	44	Occupied nests	pairs
Great cormorant	*Phalacrocorax carbo*	23	Occupied nests	pairs
Common tern	*Sterna hirundo*	48	Occupied nests	pairs

Within and around Loch Ailort, the largest concentration of breeding birds was on a group of rocky islands just to the south of the Eilean Dubh mussel site (Figure 8.1). Here a total of 37 pairs of gulls and 48 pairs of terns were recorded. Therefore, it is possible that there are increased impacts from breeding seabirds in the vicinity of these islands during the spring and summer months. Elsewhere, a total of 83 occupied nests of gulls and 6 occupied nests of shags were recorded at the mouth of the loch.

Waterfowl (ducks and geese) are likely to be present in the area at various times, primarily to overwinter, or briefly during migration, although some species breed in Lochaber in small numbers. Ten greylag geese were observed on the salt grass at the head of the loch and 8 were recorded on grassland by Roshven during the shoreline survey suggesting there is a small breeding population in the area. Geese are likely to be found on areas of pasture. Wading birds would be concentrated on intertidal areas, such as the area on which the trestles are located, although no aggregations were recorded during the shoreline survey.

Otters

No otters were observed during the course of the shoreline survey, although it is believed that they are present in the area. However, the typical population densities of coastal otters are low and their impacts on the shellfishery, if any, are expected to be very minor.

Summary

In summary, the main wildlife species potentially impacting on the production areas are deer, seals, seabirds and geese. Contamination from deer will be carried into the production area by streams draining the surrounding hills and this will occur all year round. Seals are likely to be a minor year round presence. Impacts from breeding seabirds may be higher at the Eiliean Dubh site. Geese will tend to be found on areas of pasture, and there may be greater numbers present in the winter months if they overwinter in the area. However, as all these species are highly mobile, deposition of faeces by wildlife is likely to be widely distributed around the area.

Figure 8.1 Breeding seabird counts within 5km of the shellfishery at Loch Ailort

9. Meteorological data

The nearest weather station is located at Inverailort, at the head of Loch Ailort, for which rainfall data was available for 2003-2008 inclusive apart from the month of January 2005. The nearest weather station for which wind data is available is Tiree, approximately 75 km to the south-west of the fishery. It is likely that overall wind patterns are broadly similar at Loch Ailort and at Tiree, but local topography is likely to skew their patterns in different ways, and conditions at any given time may differ due to the distance between them. This section aims to describe the local rain and wind patterns and how they may affect the bacterial quality of shellfish at Loch Ailort.

Rainfall and wind data were supplied to Cefas/FSAS by the Meteorological Office under licence. Unless otherwise identified, the content of this section (e.g. graphs) is based on further analysis of this data undertaken by Cefas.

9.1 Rainfall

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

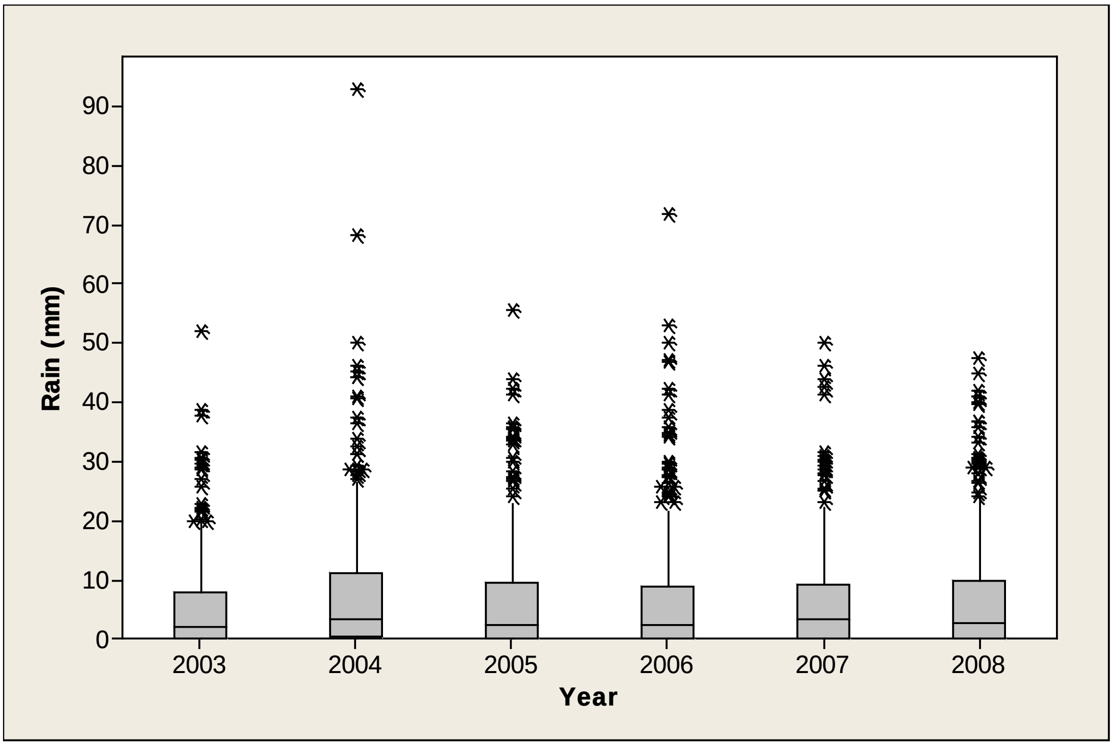

Figure 9.1 Box plot of daily rainfall values by year at Inverailort, 2003-2008

Figure 9.1 shows that rainfall patterns were similar between the years presented here, with 2003 the driest and 2004 the wettest.

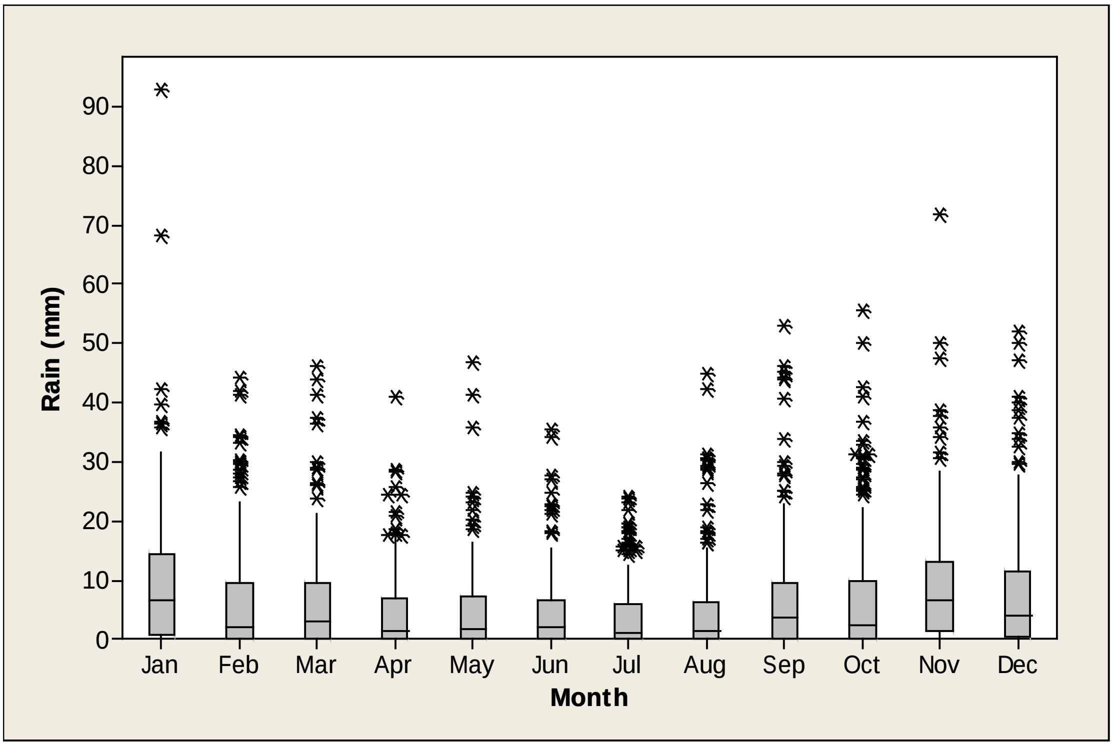

Figure 9.2 Box plot of daily rainfall values by month at Inverailort, 2005-2008

The wettest months were September to March. Days with high rainfall can occur at any time of the year although peak rainfall events in July were lower than in other months. For the period considered here (2003-2008), 39% of days experienced rainfall less than 1 mm, and 23% of days experienced rainfall of 10 mm or more, which is a relatively high frequency of high rainfall days. January, November and December had the highest number of days with rainfall greater than 10mm.

It can therefore be expected that levels of rainfall dependent faecal contamination entering the production area will be higher on average during the autumn and winter months. However, rainfall events substantially above the average can occur at any time of year, as can be seen in Figure 9.2. These events may result in a 'first flush' of highly contaminated runoff from pastures, resulting in poor water quality at the fishery. This effect may be particularly acute during the summer, when livestock numbers are likely to be highest and faecal matter may have built up on pastures. Therefore, rainfall driven runoff of faecal contamination is most likely to affect the fishery after heavy rainfall during the late summer to early autumn months.

9.2 Wind

Wind data collected at the Tiree weather station is summarised by season and presented in Figures 9.3 to 9.7.

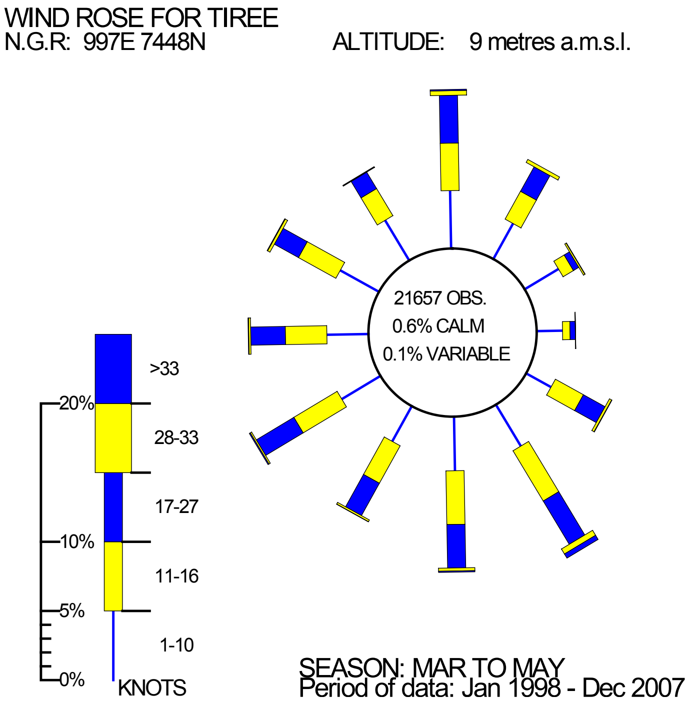

Figure 9.3 Wind rose for Tiree (March to May)

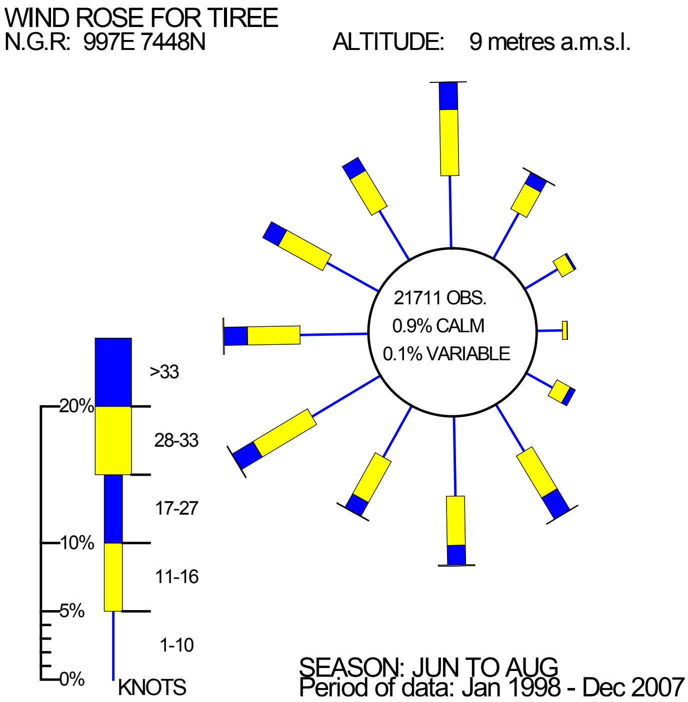

Figure 9.4 Wind rose for Tiree (June to August)

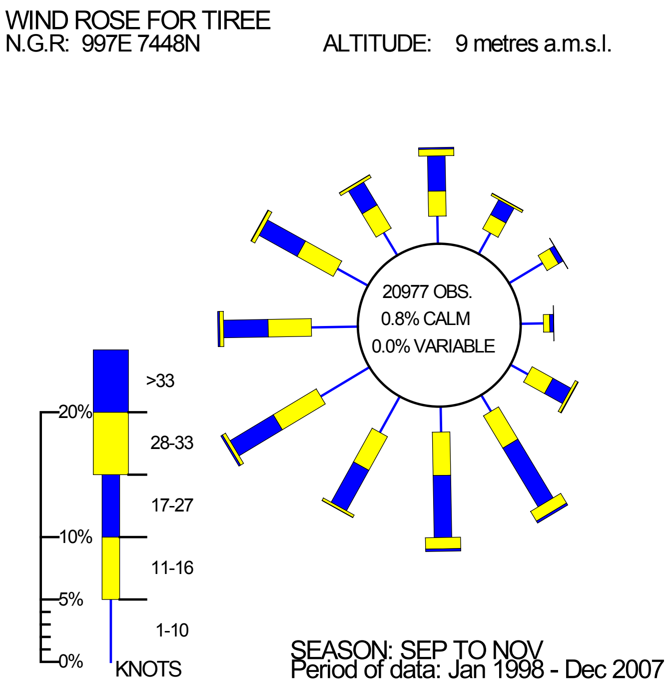

Figure 9.5 Wind rose for Tiree (September to November)

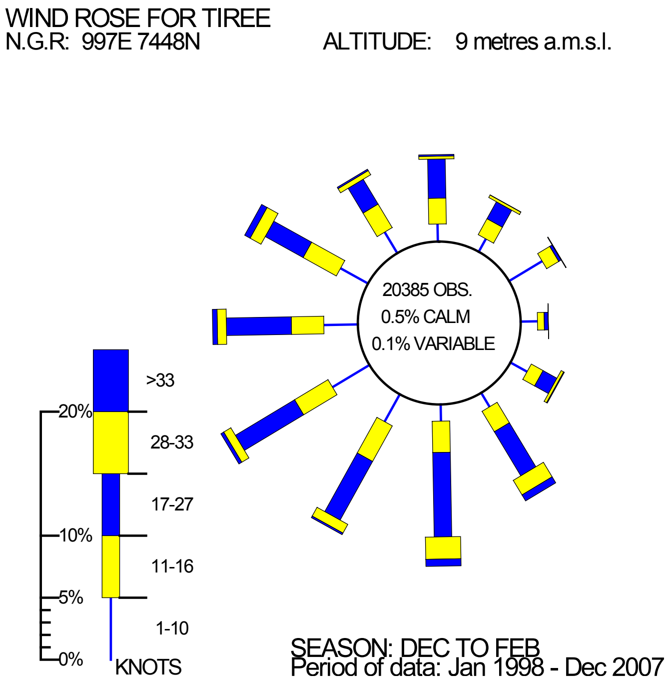

Figure 9.6 Wind rose for Tiree (December to February)

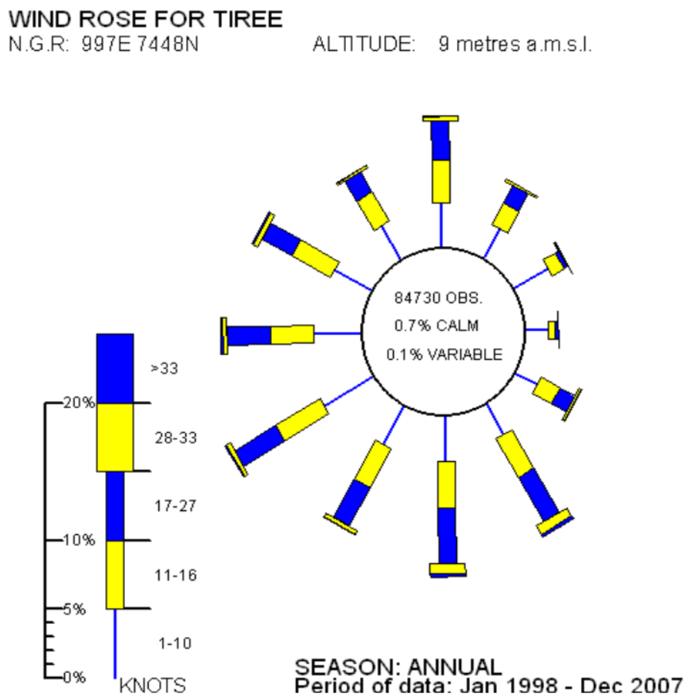

Figure 9.7 Wind rose for Tiree (All year)

The prevailing wind direction at Tiree is from the south and west, but wind direction often changes markedly from day to day with the passage of weather systems. Winds are generally lightest in the summer and strongest in the winter. There is a higher occurence of northerly winds during the first half of the year. Tiree is a low lying island exposed to Atlantic winds with a relatively high frequency of gales. Loch Ailort has an east-west aspect at its mouth and bends round to a south-west to north-east aspect towards its head. It is surrounded by hills which rise to over 800 m in places. Therefore, although it is partially exposed to the west, overall wind patterns at Loch Ailort are likely to differ from those at Tiree. Winds are likely to be funnelled up and down the loch, so the wind patterns will be skewed towards the orientation of the loch, and it is also likely that they will be generally lighter than those experienced at Tiree as Loch Ailort is more sheltered than Tiree.

Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s. Therefore strong winds may significantly alter the pattern of surface currents within Loch Ailort, subsequently affecting the movement of freshwater-associated contamination. Strong winds may affect tide height depending on wind direction and local hydrodynamics. A strong wind combined with a spring tide may result in higher than usual tides, which will carry accumulated faecal matter from livestock, in and above the normal high water mark, into the production area. A south-westerly wind will result in increased wave action at the Camus Driseach site at the head of the loch, which may resuspend any organic matter settled in the substrate.

10. Current and historical classification status

Loch Ailort has been classified for the production of mussels, Pacific oysters, native oysters and razor clams for varying periods in recent years. It is currently classified for the production of mussels, Pacific oysters and native oysters, although the classification for native oysters will lapse in 2010 as production and sampling of this species has now ceased. Classification histories for the various species are presented in Tables 10.1 to 10.4. A map of the current production area can be found in Section 2, Figure 2.1.

Table 10.1 Classification history, Loch Ailort, mussels

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	a[1]	a	a	a	a	a	b	b	b	a	a	a
2002	A	A	A	A	A	A	B	B	B	A	A	A
2003	A	A	A	A	A	A	A	A	A	A	A	A
2004	A	A	A	A	A	B	B	A	A	A	A	A
2005	A	A	A	A	A	A	A	A	A	A	A	A
2006	A	A	A	A	A	B	B	B	B	B	A	A
2007	A	A	A	A	A	B	B	B	B	B	A	A
2008	A	A	A	A	A	B	B	B	B	B	A	A
2009	A	A	A	A	A	B	B	B	A	A	A	A
2010	A	A	A	A	A	A	A	A	A	A	A	A
2011	A	A	A									

[1]lower case denotes provisional classification

For mussels, Loch Ailort has held seasonal A/B classifications throughout most of its classification history, aside from in 2003, 2005 and 2010 when it held year round A classifications. The timing and number of B months has varied from year to year, but they have always fallen between June and October.

Table 10.2 Classification history, Loch Ailort, Pacific oysters

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003	B	B	B	B	B	B	B	B	B	A	A	A
2004	A	A	A	B	B	B	B	B	B	A	A	A
2005	A	A	A	A	B	B	B	B	B	A	A	A
2006	A	A	A	A	B	B	B	B	B	A	A	A
2007	A	A	A	A	B	B	B	B	B	B	B	A
2008	A	A	A	A	B	B	B	B	B	B	B	A
2009	A	A	A	A	A	B	B	B	B	B	B	A
2010	A	A	A	B	B	B	B	B	B	B	B	B
2011	B	B	B									

For Pacific oysters, Loch Ailort has held seasonal A/B classifications throughout its classification history. The timing and number of B months has varied from year to year, although the months from June to September have held B classifications every year. The classification in 2010 has recently been changed to year-round class B.

Table 10.3 Classification history, Loch Ailort, native oysters

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

For native oysters, Loch Ailort has held seasonal A/B classifications throughout its classification history. The timing and number of B months has varied from year to year, although the months from July to October have held B classifications every year.

Table 10.4 Classification history, Loch Ailort, razor clams

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	B	B	B	B	B	B	B	B	B	A	A	B

For razor clams, the area received a seasonal A/B classification in 2005, with only October and November holding Class A classifications. It has not been classified for these species since.

In general, where seasonal classifications have applied for mussels, Pacific and native oysters, the lower classification has applied in the summer/autumn period.

11. Historical *E. coli* data

11.1 Validation of historical data

All shellfish samples taken Loch Ailort from the beginning of 2002 up to the 28th September 2009 were extracted from the database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data.

No samples were excluded from the analysis on the basis of geographical or sampling date discrepancies. One mussel sample was found to have the wrong site and sampling location entered onto the database when details were checked back to the original sampling submission form, and these were amended.

Thirteen mussel samples, 17 native oyster samples, 10 Pacific oyster samples and 6 razor samples had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation. One mussel sample had the result reported as >18000, and this was assigned a nominal value of 36000 for those purposes.

All *E. coli* results are reported in most probable number (MPN) per 100g of shellfish flesh and intravalvular fluid.

11.2 Summary of microbiological results

A summary of all sampling and results by site and species are presented in Table 11.1. Results for native oysters from Eilean nan Gualainn and for razors from Loch Ailort Outer are presented in the summary table, and on the maps of geometric mean result by sampling location, but could not be used in the more detailed analysis of temporal trends and responses to environmental factors as sample numbers were too low for these sites/species.

Table 11.1 Summary of historical sampling and results

Sampling Summary					
Production area	Loch Ailort	Loch Ailort	Loch Ailort	Loch Ailort	Loch Ailort
Site	Site 1 - Muckairn Mussels	Camus Driseach	Camus Driseach	Eilean na Gualainn	Outer
Species	Common mussels	Pacific oysters	Native oysters	Native oysters	Razors
SIN	HL-114-214-08	HL-114-207-13	HL-114-207-12	HL-114-210-12	HL-114-213-16
Location	12 locations	9 locations	2 locations	NM724788	6 locations
Total no of samples	61	75	47	12	10
No. 2002	8	9	0	0	0
No. 2003	8	12	2	0	0
No. 2004	7	9	9	6	8
No. 2005	11	11	11	6	2
No. 2006	8	12	11	0	0
No. 2007	6	7	7	0	0
No. 2008	6	7	7	0	0
No. 2009	7	8	0	0	0
Results Summary					
Minimum	<20	<20	<20	<20	<20
Maximum	>18000	16000	5400	9100	130
Median	40	200	110	20	<20
Geometric mean	63.5	205	108	46.0	15.9
90 percentile	310	3500	1300	481	31.0
95 percentile	700	6510	1610	4370	80.5
No. exceeding 230/100g	9 (15%)	34 (45%)	19 (40%)	3	0
No. exceeding 1000/100g	3 (5%)	21 (28%)	7 (15%)	1	0
No. exceeding 4600/100g	3 (5%)	6 (8%)	1 (2%)	1	0
No. exceeding 18000/100g	1 (2%)	0 (0%)	0 (0%)	0	0

11.3 Overall geographical pattern of results

Figures 11.1 to 11.4 present maps showing *E. coli* results by reported sampling locations for mussels, Pacific oysters, native oysters and razors respectively.

<u>Mussels</u>

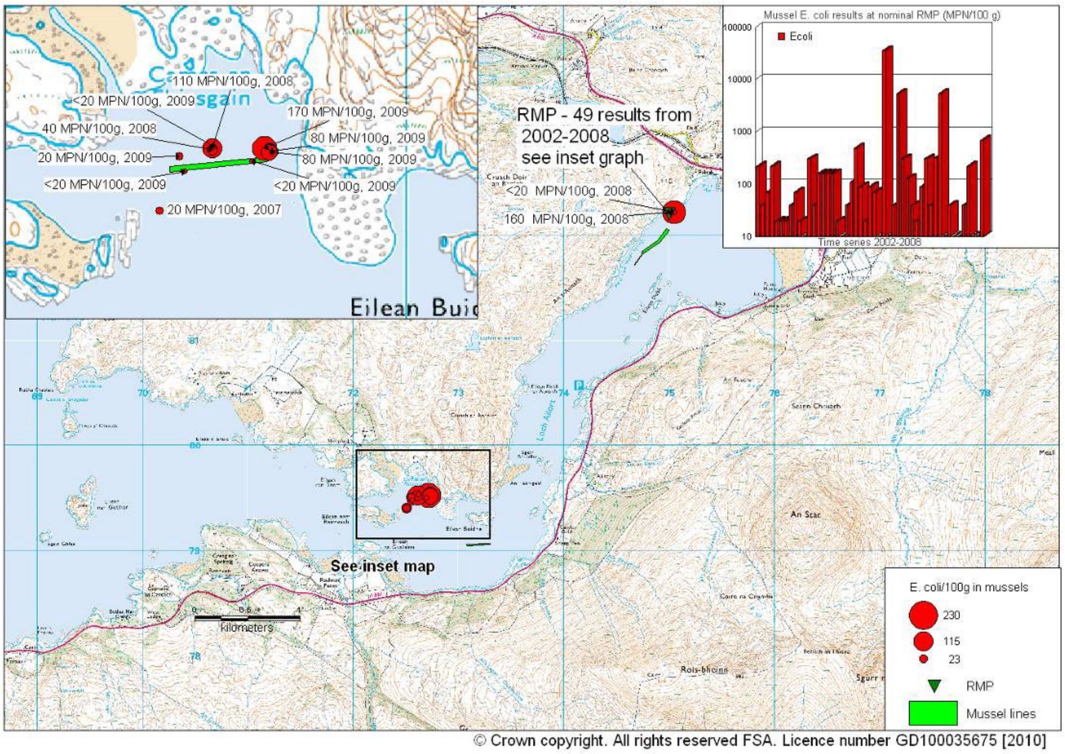

Figure 11.1 Map of sampling points and individual/geometric mean *E. coli* result (mussels, Site 1 – Muckairn Mussels)

Although these samples are reported to originate from the same site, they fall in two distinct clusters, one at the nominal RMP and one at the actual site. It is believed that the former were actually taken from the actual site, but it is not possible to verify this. There was no significant difference between these two clusters in mean result (T-test, T=1.79, p=0.089, Appendix 6) or proportion of results exceeding 230 *E. coli* MPN/100g (Fisher's exact, p=0.332, Appendix 6). Within the southern cluster, there is the impression of higher results towards the eastern end of the Muckairn Mussels site.

Pacific oysters

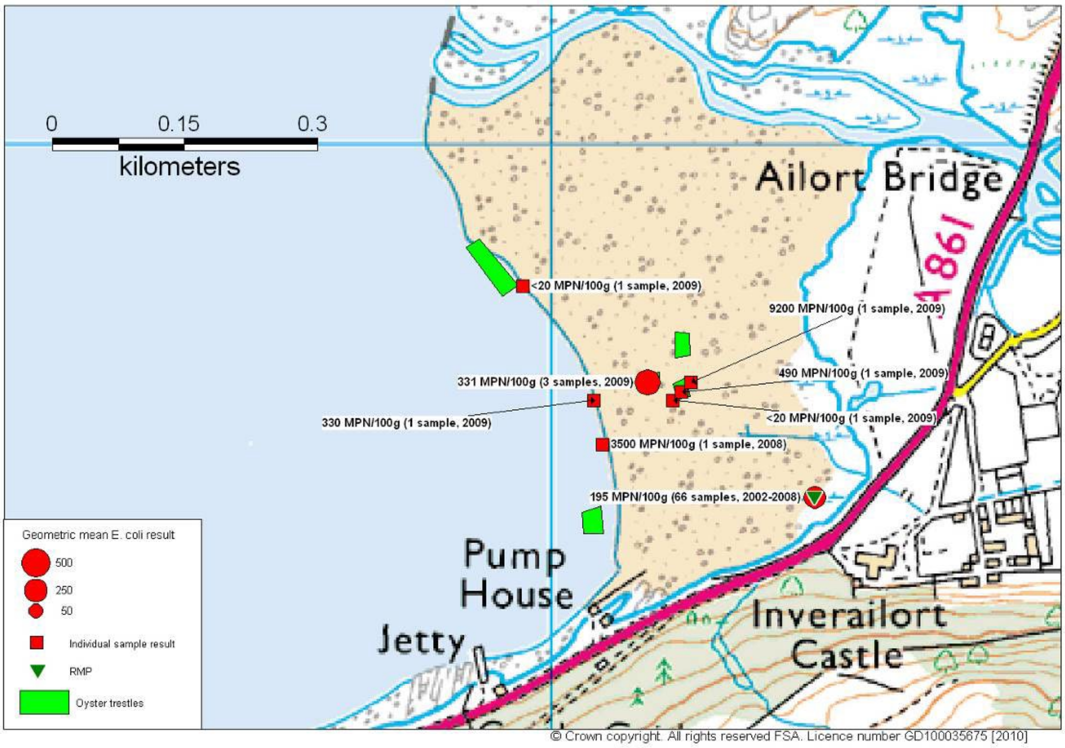

Figure 11.2 Map of sampling points and individual/geometric mean *E. coli* result (Pacific oysters, Camus Driseach)

The vast majority of samples were reported from the RMP, and all samples were reported from a relatively small area. No geographical patterns are apparent in Figure 3.1.

Native oysters

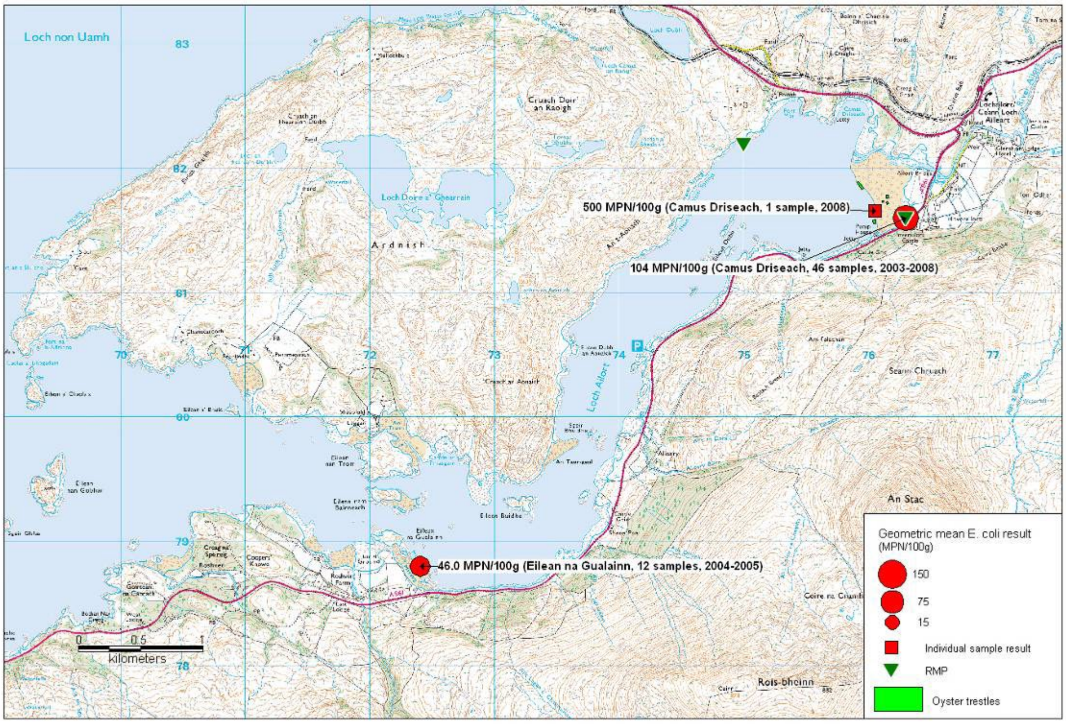

Figure 11.3 Map of sampling points and individual/geometric mean *E. coli* result (Native oysters, Camus Driseach and Eilean na Gualainn)

Both of these sites were native oyster sites sampled on the same day and hence under approximately the same environmental conditions on a total of 10 occasions. A comparison of these results reveals that although the geometric mean result was higher for Camus Driseach (41.8 *E. coli* MPN/100g) than for Eilean nan Gualainn (29.5 *E. coli* MPN/100g) this difference was not statistically significant (Paired T-test, T=0.59, p=0.573).

Razor clams

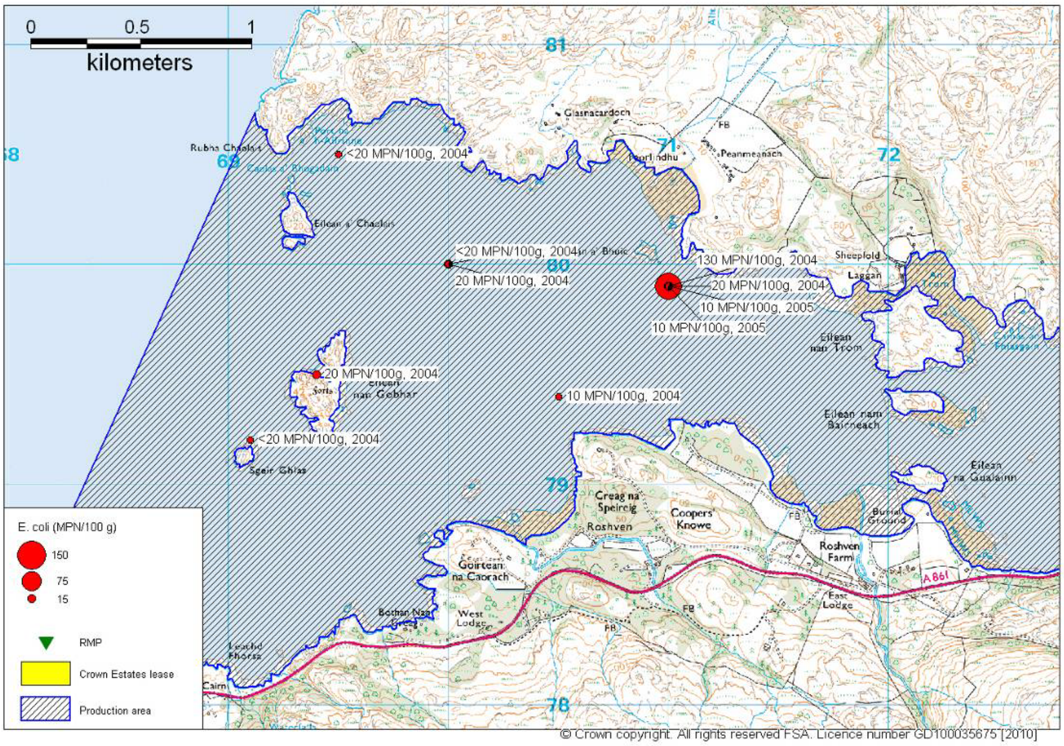

Figure 11.4 Map of sampling points and individual *E. coli* results (Razor clams, Outer)

Sample numbers are low, as were levels of contamination. The highest result (130 *E. coli* MPN/100 g) was found at the easternmost sampling location. Three other samples taken at that location gave much lower results.

11.4 Overall temporal pattern of results

Figures 11.5 to 11.7 present scatter plots of individual results against date for mussels from Site 1 – Muckairn Mussels, Pacific oysters from Camus Driseach and Native oysters from Camus Driseach, fitted with trend lines calculated using two different techniques. They are fitted with lines indicating the geometric mean of the previous 5 samples, the current sample and the following 6 samples, referred to as a rolling geometric mean (black line). They are also fitted with loess lines (blue lines), which 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. These trend lines help to highlight any apparent underlying trends or cycles.

<u>Mussels</u>

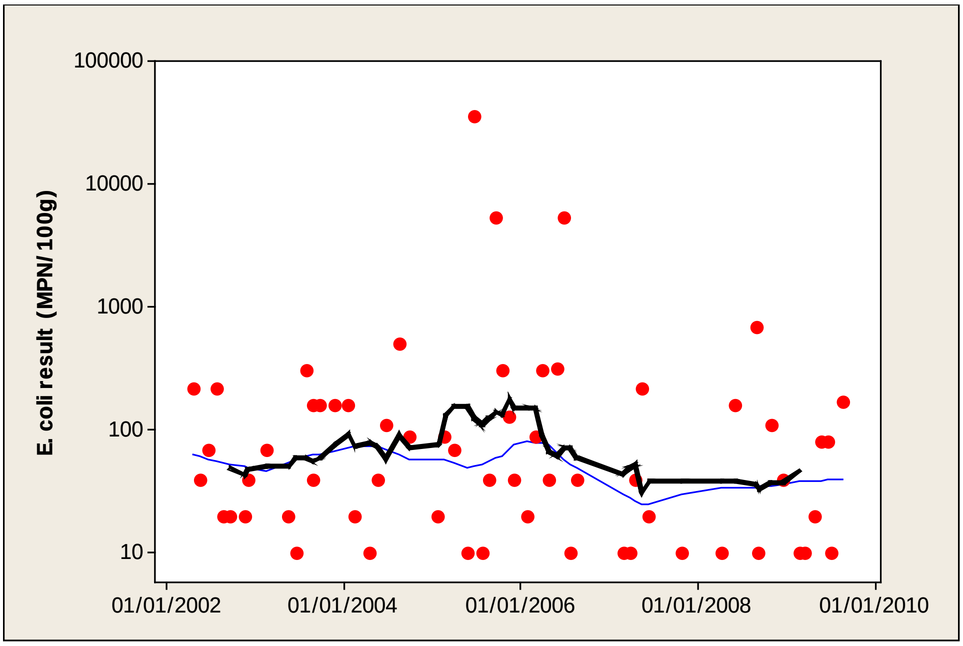

Figure 11.5 Scatterplot of *E. coli* results by date with rolling geometric mean (black line) and loess line (blue line) (mussels from Site 1- Muckairn mussels)

Figure 11.5 shows that the highest results occurred in 2005 and 2006, but aside from that no other trends or cycles are apparent.

Pacific oysters

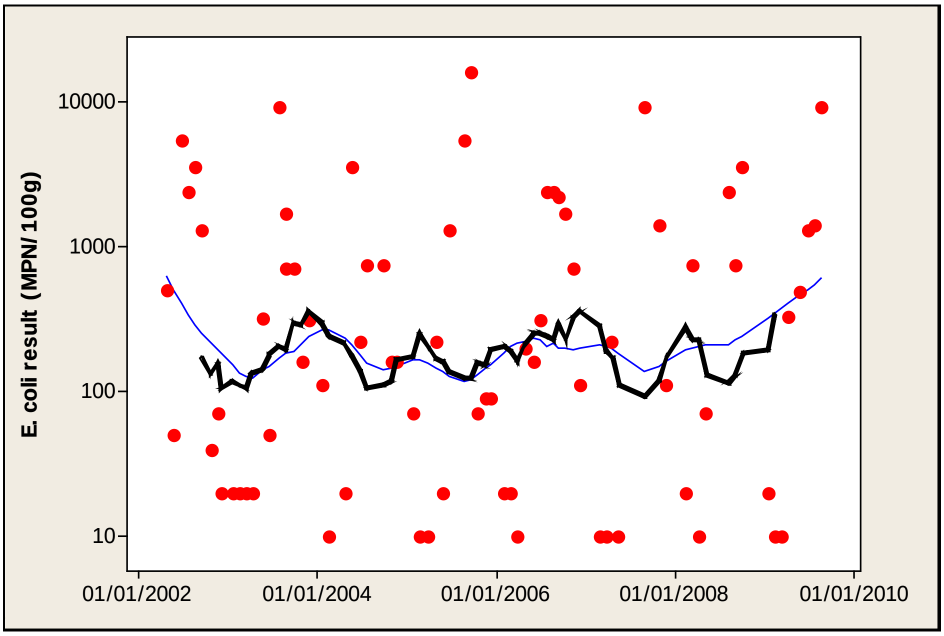

Figure 11.6 Scatterplot of *E. coli* results by date with rolling geometric mean (black line) and loess line (blue line) (Pacific oysters from Camus Driseach)

No overall trends or cycles are apparent in Figure 11.6.

Native oysters

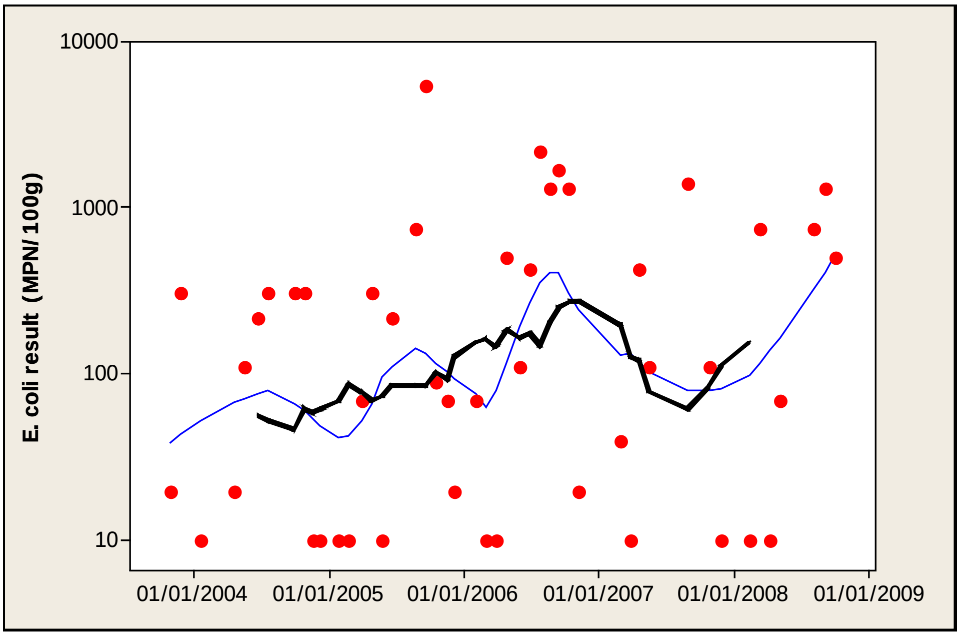

Figure 11.7 Scatterplot of *E. coli* results by date with rolling geometric mean (black line) and loess line (blue line) (native oysters from Camus Driseach)

The loess line suggests that there was some seasonal fluctuation in results in 2004, 2005 and 2006, with peaks in the summer months.

11.5 Seasonal pattern of results

11.5.1 *E. coli* results by month

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns of human occupation, which in turn can affect levels of microbial contamination. Figures 11.8, 11.9 and 11.10 present scatterplots with loess lines of *E. coli* result by month for mussels from Site 1 – Muckairn mussels, Pacific oysters from Camus Driseach and Native oysters from Camus Driseach respectively.

Mussels

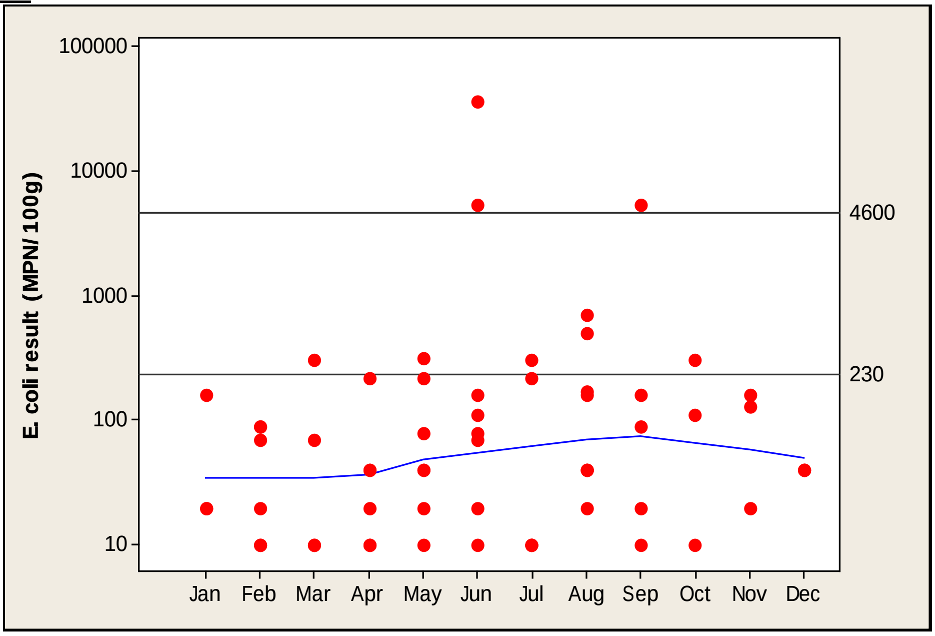

Figure 11.8 Scatterplot of results by month (mussels from Site 1- Muckairn Mussels)

Higher results occurred in June and September, although there is no clear seasonal pattern.

Pacific oysters

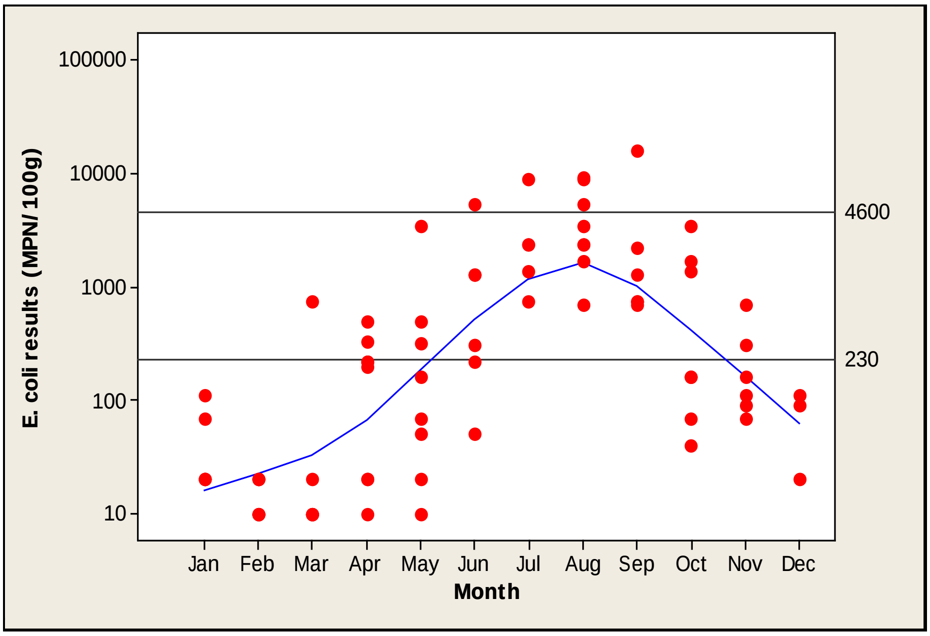

Figure 11.9 Scatterplot of results by month (Pacific oysters from Camus Driseach)

A very strong seasonal pattern is apparent in Figure 11.9, with results much higher in the warmer months and much lower in the colder months.

Native oysters

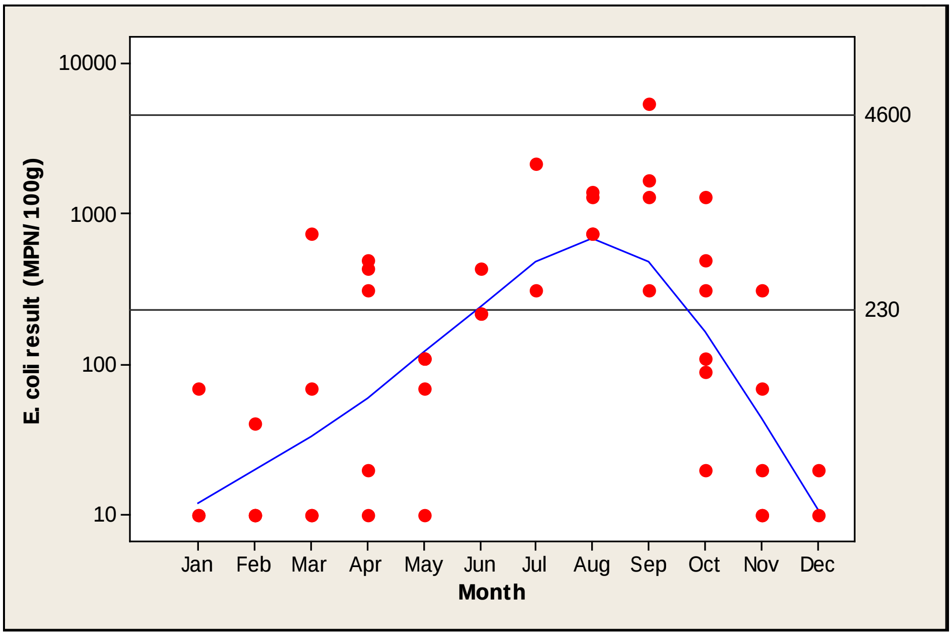

Figure 11.10 Scatterplot of results by month (native oysters from Camus Driseach)

A very strong seasonal pattern is apparent in Figure 11.10, with highest results occurring during the warmer months of the year, a very similar pattern to that observed in Pacific oysters from the same site.

11.5.2 *E. coli* result by season

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

<u>Mussels</u>

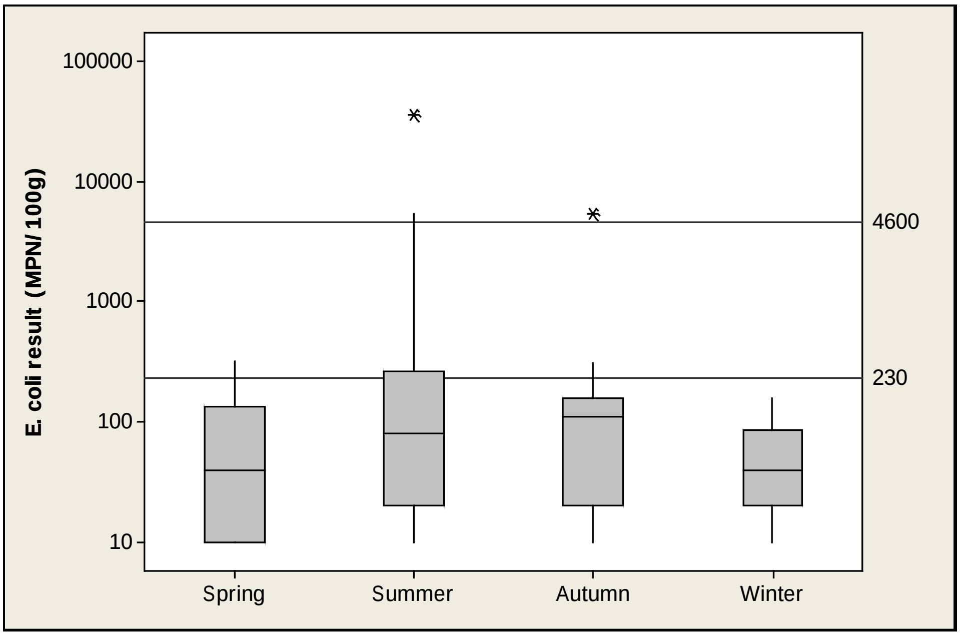

Figure 11.11 Boxplot of result by season (mussels from Site 1- Muckairn Mussels)

No significant difference was found between results by season for the mussels from Site 1- Muckairn Mussels (One-way ANOVA, p=0186, Appendix 6).

Pacific oysters

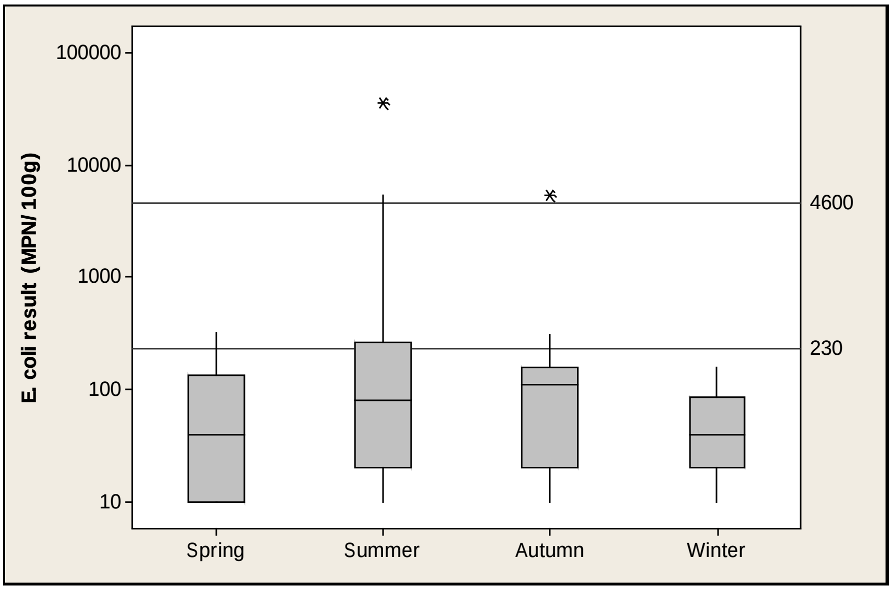

Figure 11.12 Boxplot of result by season (Pacific oysters from Camus Driseach)

A highly significant difference was found between results by season for Pacific oysters from Camus Driseach (One-way ANOVA, p=0.000, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicates that results for the summer were significantly higher than those for all other seasons, and results for the autumn were significantly higher than for the winter and spring.

Native oysters

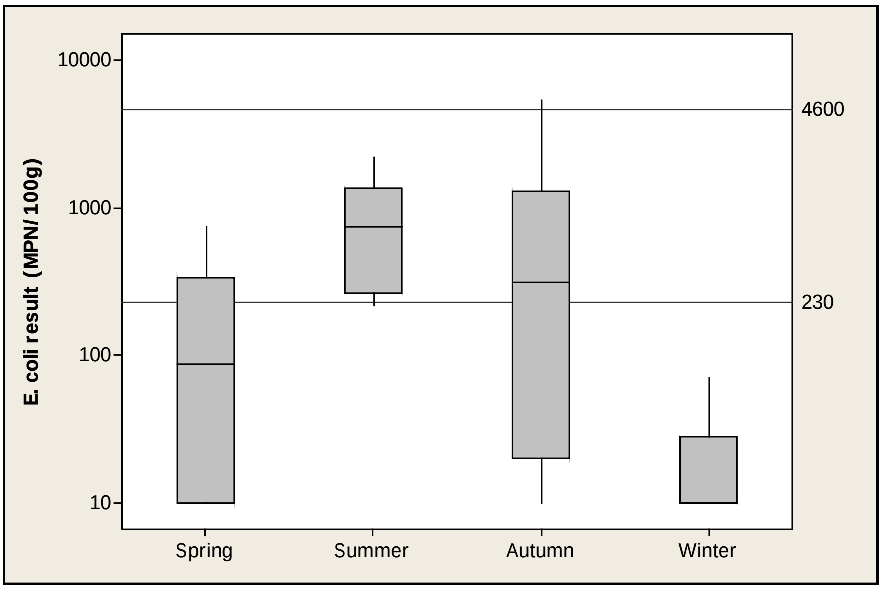

Figure 11.13 Boxplot of result by season (native oysters from Camus Driseach)

A highly significant difference was found between results by season for native oysters from Camus Driseach (One-way ANOVA, p=0.000, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicates that results for the summer were significantly higher than those in the winter and spring, and results for the autumn were significantly higher than those for the winter.

11.6 Analysis of results against environmental factors

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

11.6.1 Analysis of results by recent rainfall

The nearest weather station is at Inverailort, at the head of Loch Ailort. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2008 (total daily rainfall in mm). Figures 11.14, 11.15 and 11.16 present scatterplots of *E. coli* results against rainfall for mussels from Site 1 – Muckairn mussels, Pacific oysters from Camus Driseach and Native oysters from Camus Driseach respectively. Spearman's Rank correlations were carried out between shellfish *E. coli* results and rainfall.

11.6.1.1 Two-day rainfall

<u>Mussels</u>

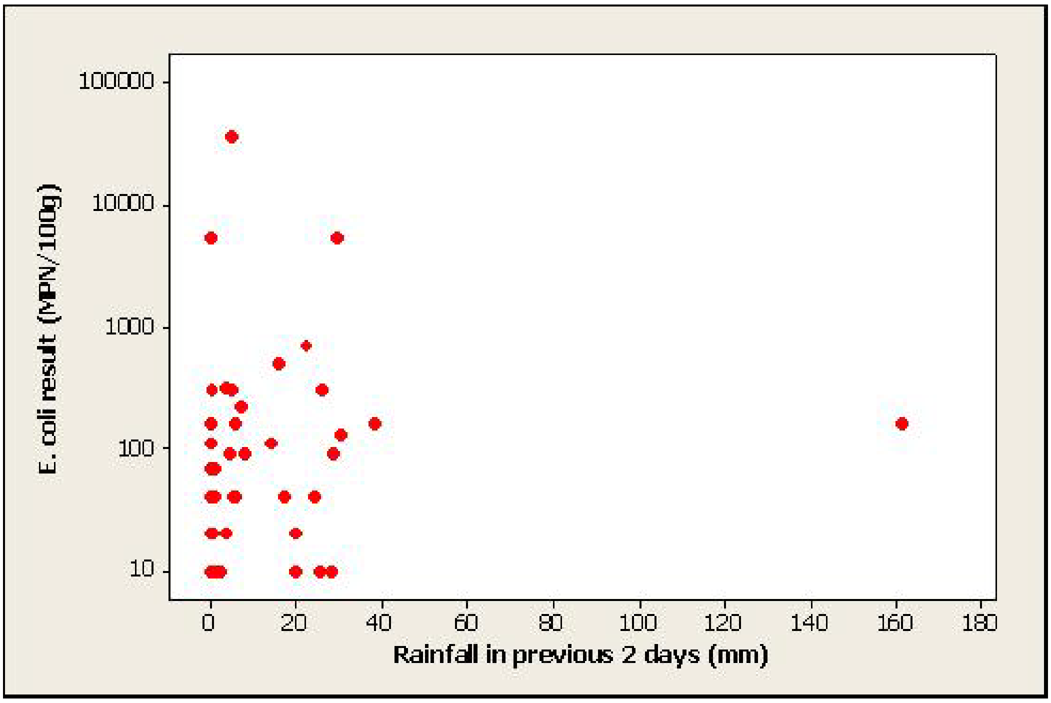

Figure 11.14 Scatterplot of result against rainfall in previous 2 days (mussels from Site 1- Muckairn mussels)

No correlation was found between *E. coli* result for mussels from Site 1 – Muckairn mussels and rainfall in the previous 2 days (Spearman's rank correlation=0.215, p=0.156, Appendix 6).

Pacific oysters

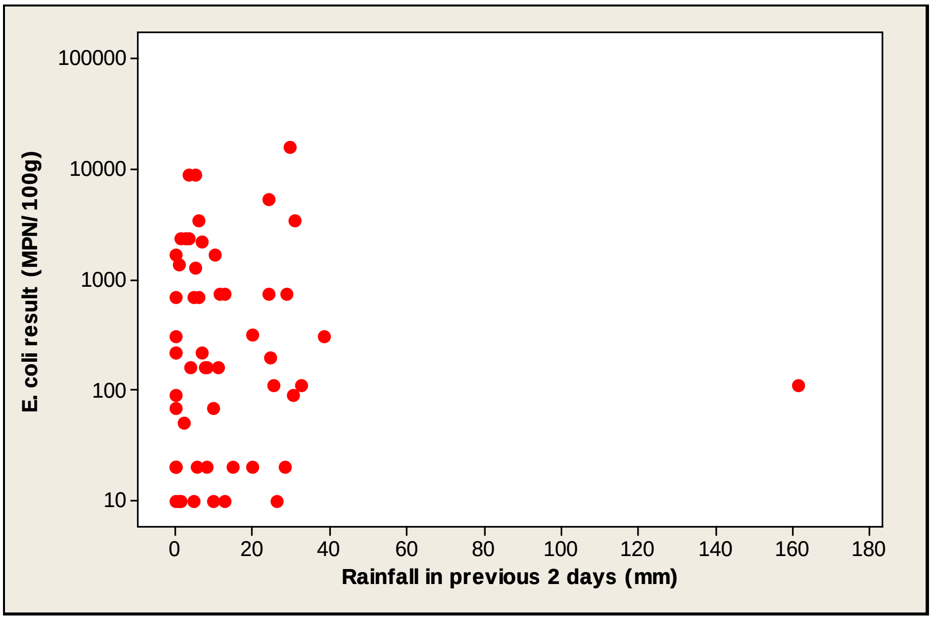

Figure 11.15 Scatterplot of result against rainfall in previous 2 days (Pacific oysters from Camus Driseach)

No correlation was found between *E. coli* result for Pacific oysters from Camus Driseach and rainfall in the previous 2 days (Spearman's rank correlation=0.128, p=0.343, Appendix 6).

Native oysters

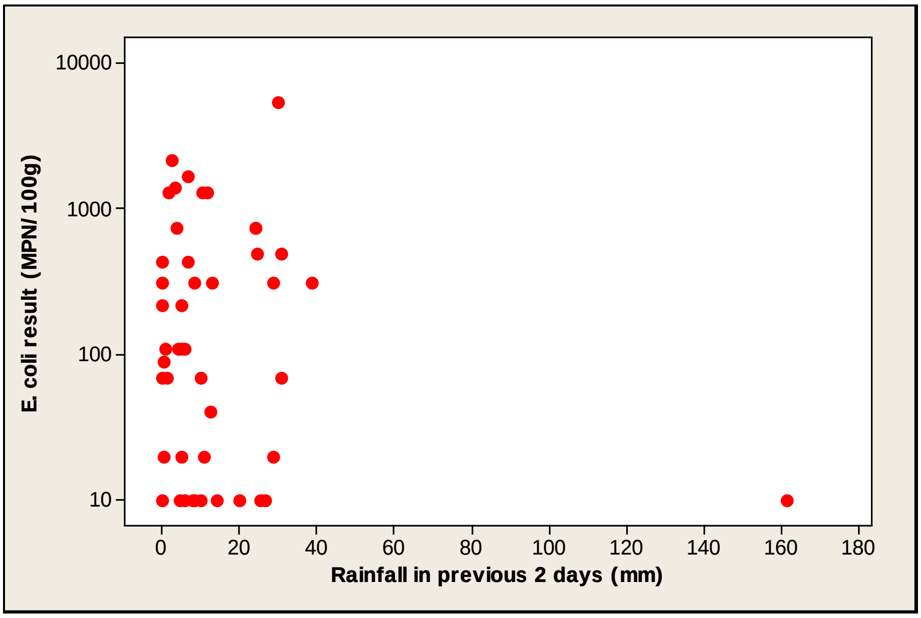

Figure 11.16 Scatterplot of result against rainfall in previous 2 days (native oysters from Camus Driseach)

No correlation was found between *E. coli* result for native oysters from Camus Driseach and rainfall in the previous 2 days (Spearman's rank correlation=-0.044, p=0.771, Appendix 6).

11.6.1.2 Seven-day 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.

<u>Mussels</u>

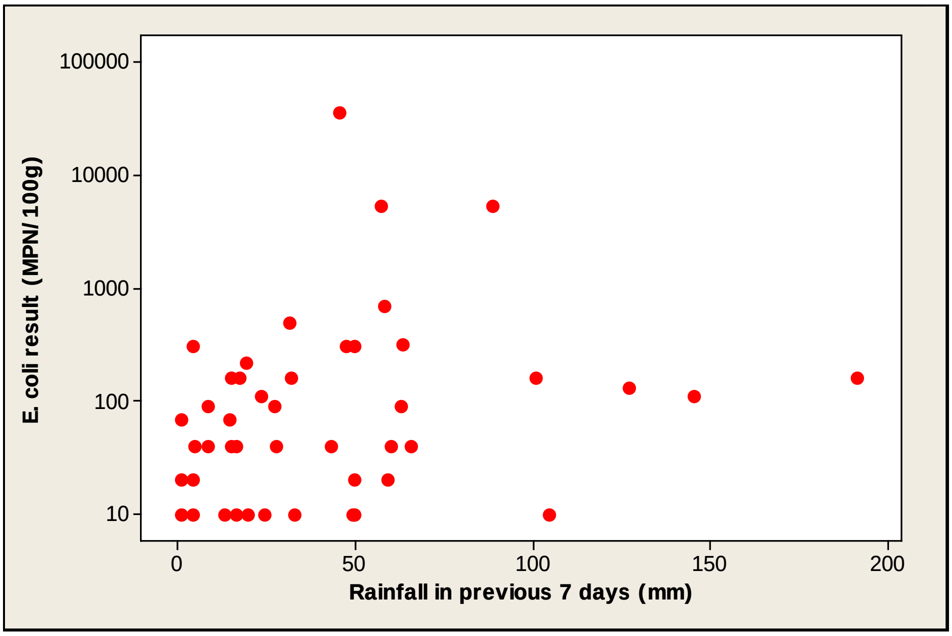

Figure 11.17 Scatterplot of result against rainfall in previous 7 days (mussels from Site 1- Muckairn mussels)

A weak positive correlation was found between *E. coli* result for mussels from Site 1 – Muckairn mussels and rainfall in the previous 7 days (Spearman's rank correlation=0.305, p=0.041, Appendix 6). However, extremely high rainfall (>100mm in seven days) did not result in high *E. coli* results.

Pacific oysters

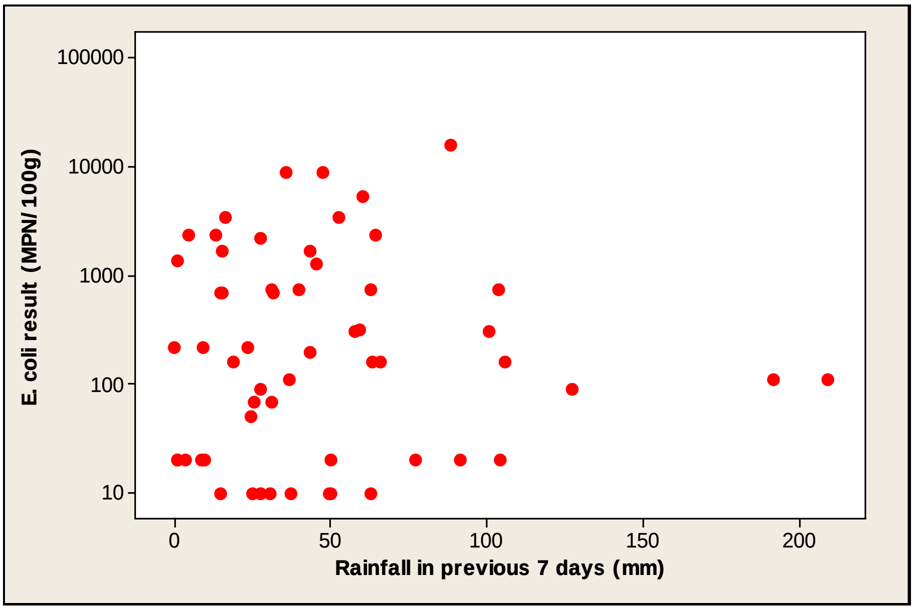

Figure 11.18 Scatterplot of result against rainfall in previous 7 days (Pacific oysters from Camus Driseach)

No correlation was found between *E. coli* result for Pacific oysters from Camus Driseach and rainfall in the previous 7 days (Spearman's rank correlation=0.043, p=0.750, Appendix 6).

Native oysters

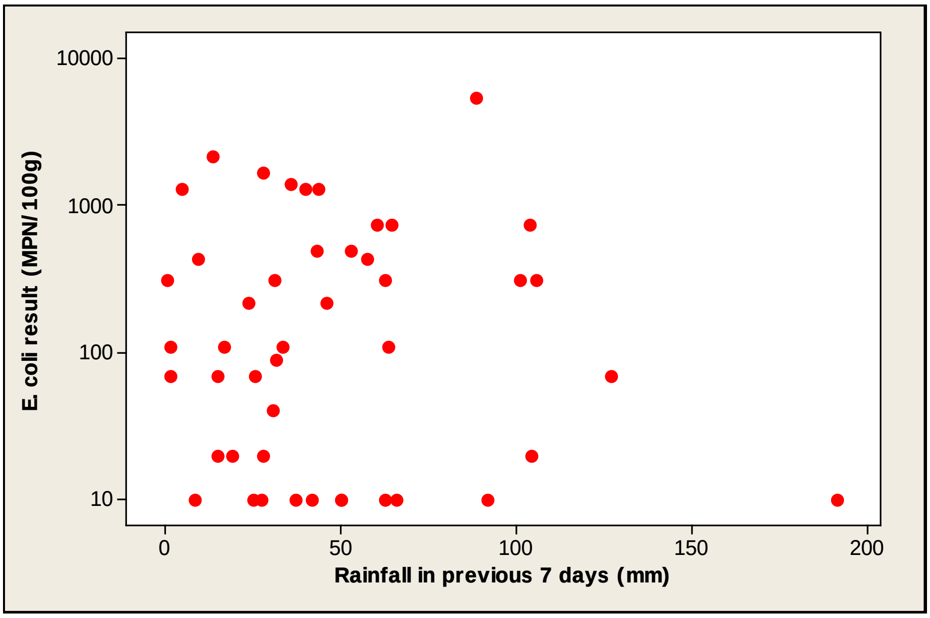

Figure 11.19 Scatterplot of result against rainfall in previous 7 days (native oysters from Camus Driseach)

No correlation was found between *E. coli* for native oysters from Camus Driseach and rainfall in the previous 7 days (Spearman's rank correlation=-0.006, p=0.968, Appendix 6). The highest rainfall value coincided with the lowest *E. coli* result.

11.6.2 Analysis of results by tidal height and state

11.6.2.1 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 loch. Figures 11.20 to 11.22 present polar plots of $\log_{10}$ *E. coli* results on the lunar spring/neap tidal cycle for mussels from Site 1 – Muckairn Mussels, Pacific oysters from Camus Driseach and Native oysters from Camus Driseach respectively. Full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of under 230 *E. coli* MPN/100g are plotted in green, those between 230 and 4600 *E. coli* MPN/100g are plotted in yellow, and those over 4600 *E. coli* MPN/100g are plotted in red. 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.

<u>Mussels</u>

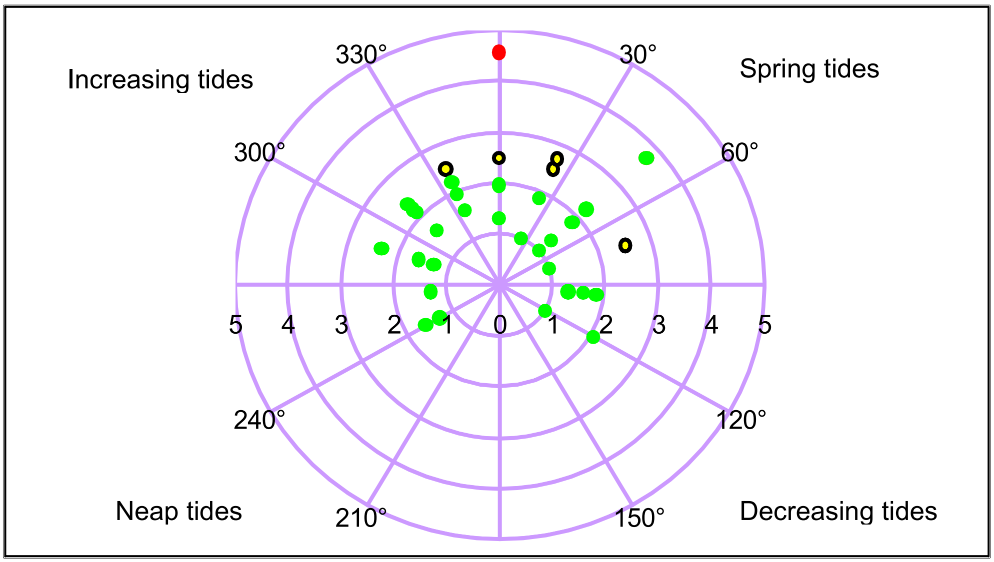

Figure 11.20 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle (mussels from Site 1 – Muckairn Mussels)

A weak correlation was found between *E. coli* results and the spring/neap cycle for mussels from Site 1 – Muckairn Mussels (circular-linear correlation, r=0.343, p=0.013, Appendix 6) suggesting that levels of *E. coli* in mussels here were not random with respect to this tidal cycle. Tentatively, it appears results were generally higher on increasing and spring tides, but few samples were taken on neap tides.

Pacific oysters

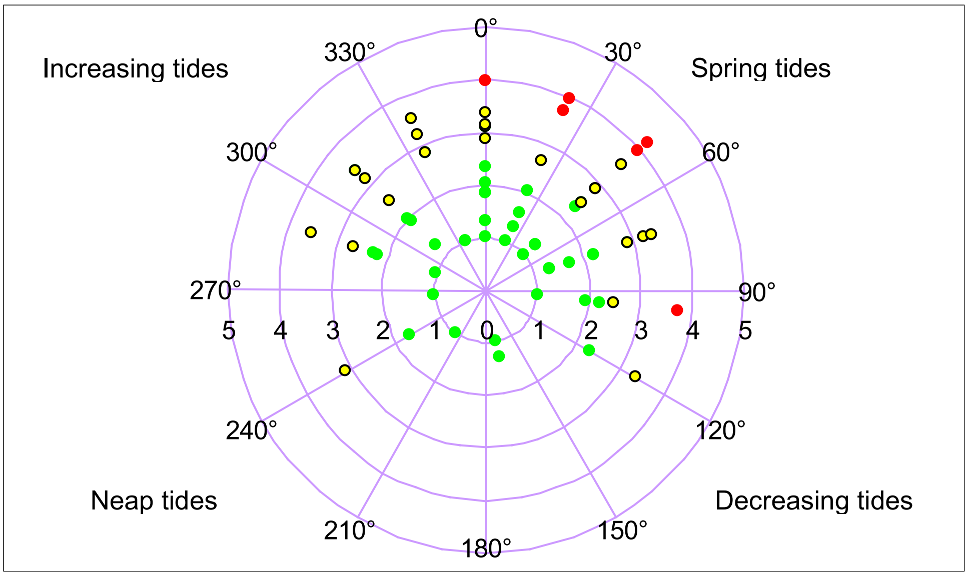

Figure 11.21 Polar plot of log_{10} *E. coli* results on the spring/neap tidal cycle (Pacific oysters from Camus Driseach)

No correlation was found between *E. coli* results and the spring/neap cycle for Pacific oysters from Camus Driseach (circular-linear correlation, r=0.165, p=0.141, Appendix 6). Sampling was targeted towards spring tides.

Native oysters

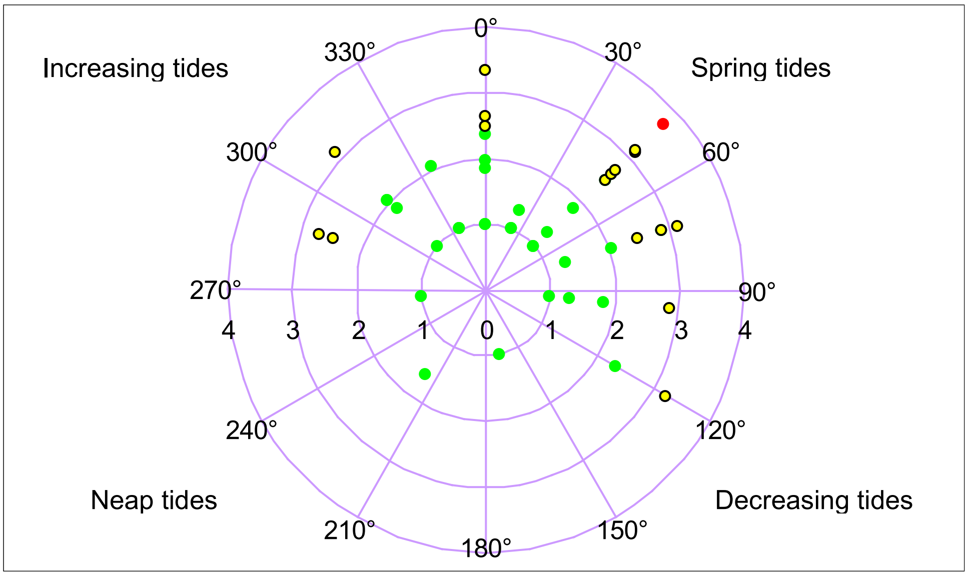

Figure 11.22 Polar plot of log_{10} *E. coli* results on the spring/neap tidal cycle (Native oysters from Camus Driseach)

No correlation was found between *E. coli* results and the spring/neap cycle for native oysters from Camus Driseach (circular-linear correlation, r=0.187, p=0.214, Appendix 6). Sampling was targeted towards spring tides.

11.6.2.2 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. Figures 11.23 to 11.25 present polar plots of log-10 *E. coli* results on the lunar high/low tidal cycle for mussels from Site 1 – Muckairn mussels, Pacific oysters from Camus Driseach and Native oysters from Camus Driseach respectively. High water is at 0º, and low water is at 180º. Again, results of under 230 *E. coli* MPN/100g are plotted in green, those between 230 and 4600 *E. coli* MPN/100g are plotted in yellow, and those over 4600 *E. coli* MPN/100g are plotted in red.

<u>Mussels</u>

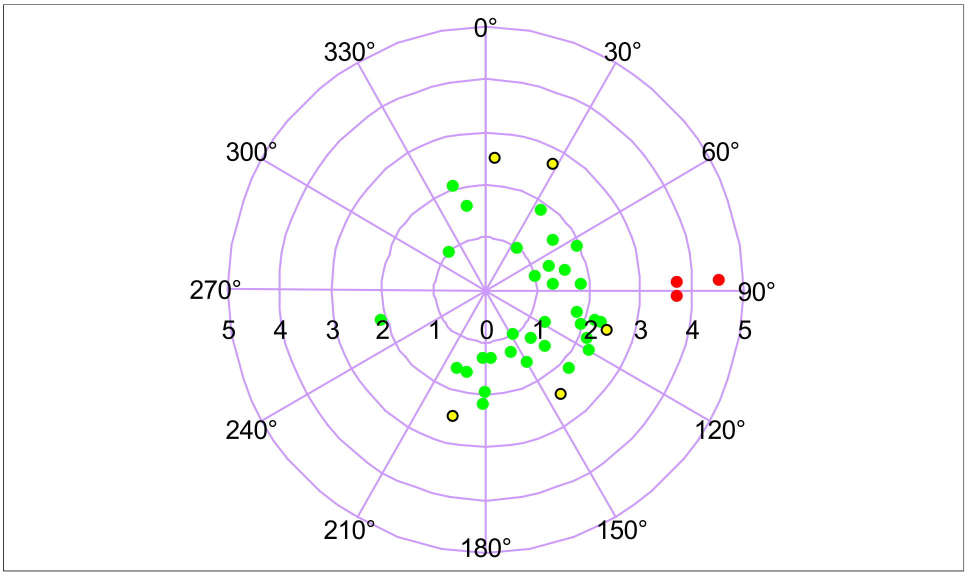

Figure 11.23 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle (mussels from Site 1 – Muckairn Mussels)

No correlation was found between *E. coli* results and the high/low tidal cycle was found for mussels from Site 1 – Muckairn Mussels (circular-linear correlation, r=0.219, p=0.169, Appendix 6). Sampling effort concentrated on falling tides, with highest results occurring at the middle of the falling tide.

Pacific oysters

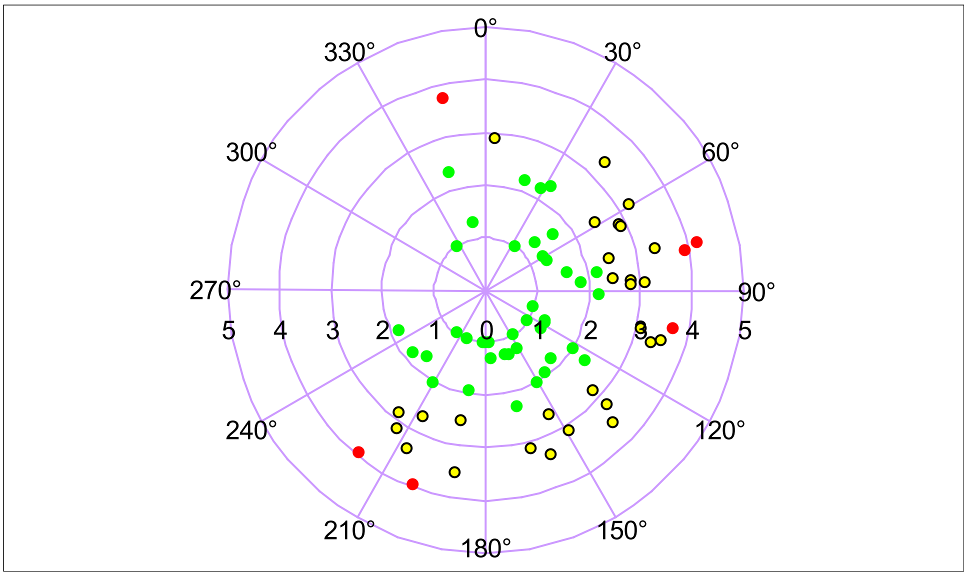

Figure 11.24 Polar plot of log_{10} *E. coli* results on the high/low tidal cycle (Pacific oysters from Camus Driseach)

No correlation was found between *E. coli* results and the high/low tidal cycle was found for Pacific oysters from Camus Driseach (circular-linear correlation, r=0.105, p=0.450, Appendix 6).

Native oysters

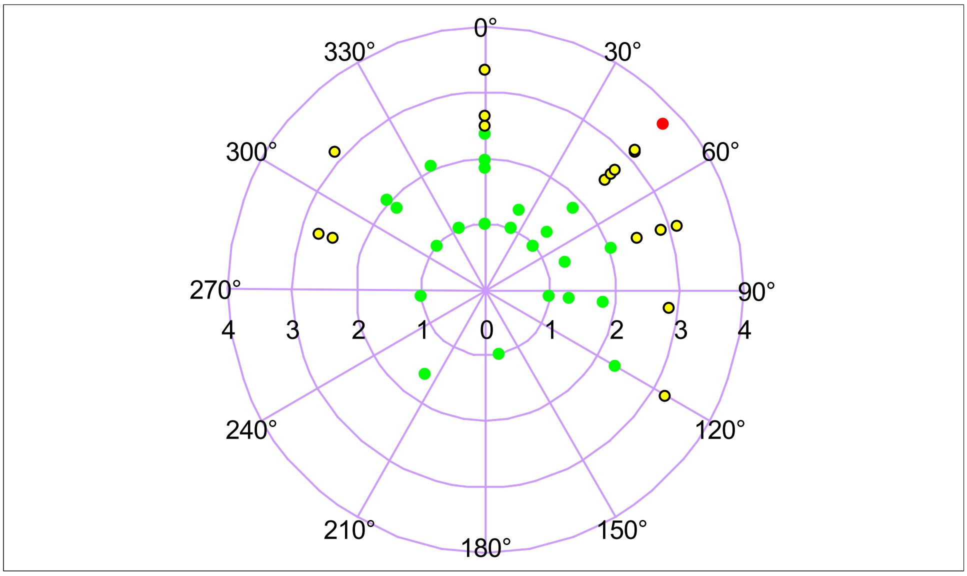

Figure 11.25 Polar plot of log_{10} *E. coli* results on the high/low tidal cycle (Native oysters from Camus Driseach)

No correlation was found between *E. coli* results and the high/low tidal cycle was found for native oysters from Camus Driseach (circular-linear correlation, r=0.187, p=0.214, Appendix 6).

11.6.3 Analysis of results by water temperature

Water temperature is likely to affect the survival time of bacteria in seawater (Burkhardt *et al*, 2000) and the feeding and elimination rates of shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. It is of course closely related to season, and so any correlation between temperatures and *E. coli* levels in shellfish flesh may not be directly attributable to temperature, but to other factors such as seasonal differences in livestock grazing patterns. Figure 11.26 presents a scatterplot of *E. coli* results against water temperature for mussels from Site 1 – Muckairn mussels, and Figure 11.27 presents the same for Pacific oysters from Camus Driseach. Water temperature was only recorded on 6 sampling occasions for native oysters from Camus Driseach, so it was not possible to investigate the relationship between water temperature and *E. coli* results at this site in a meaningful way.

<u>Mussels</u>

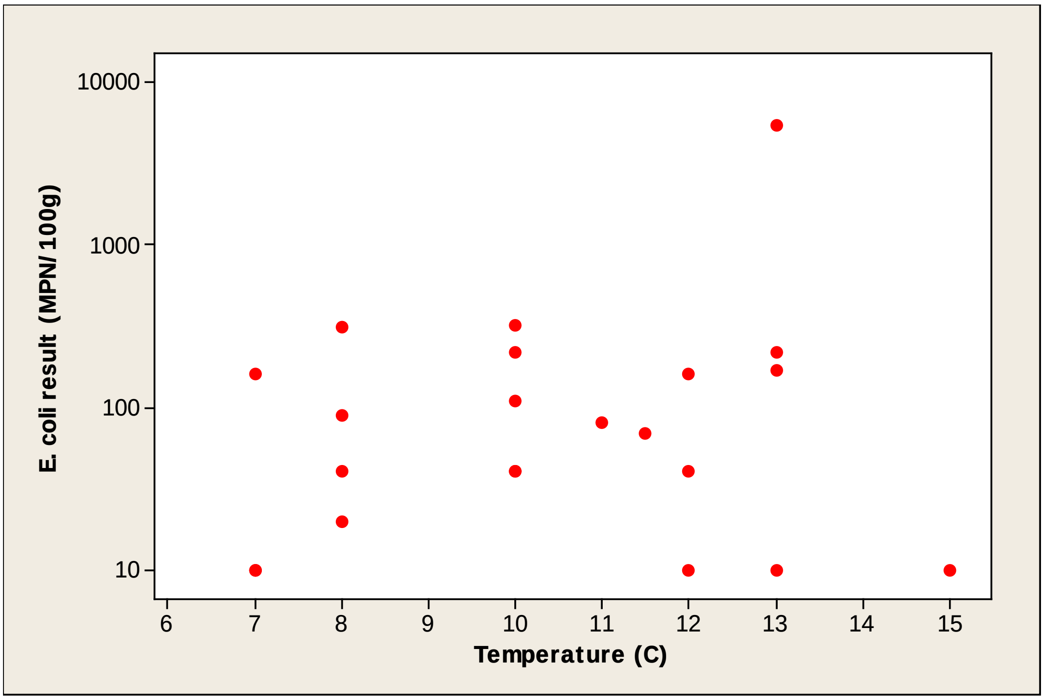

Figure 11.26 Scatterplot of result by water temperature (mussels from Site 1 – Muckairn Mussels)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and water temperature for mussels from Site 1 – Muckairn Mussels (Adjusted R-sq=0.0%, p=0.571, Appendix 6)

Pacific oysters

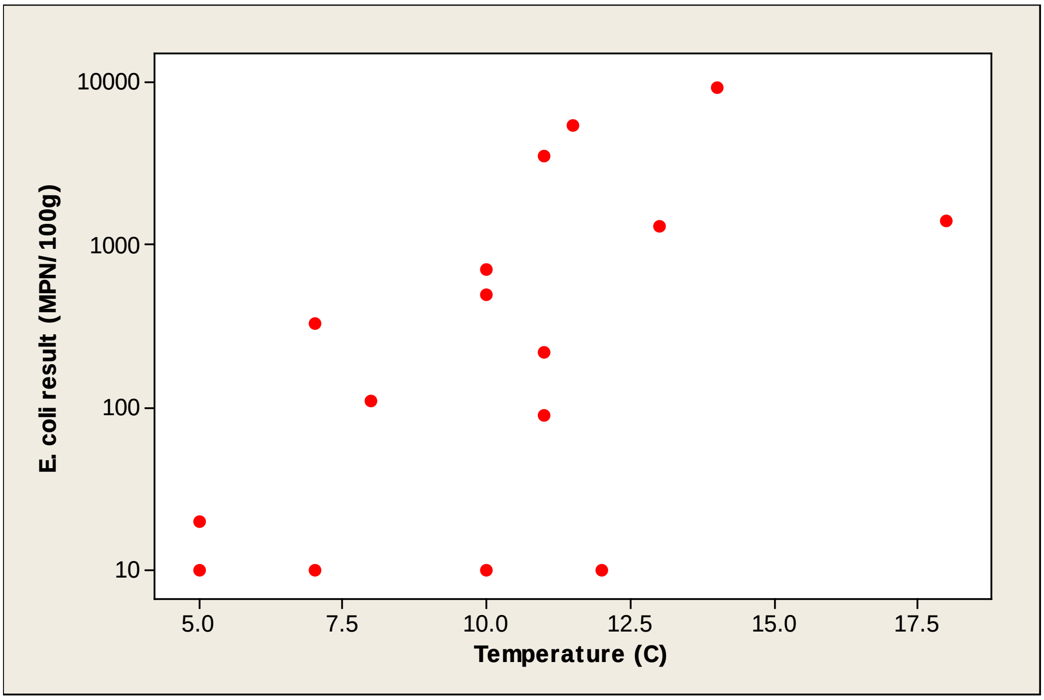

Figure 11.27 Scatterplot of result by water temperature (Pacific oysters from Camus Driseach)

The coefficient of determination indicates that there was a positive relationship between the *E. coli* result and water temperature for Pacific oysters from Camus Driseach (Adjusted R-sq=31.7%, p=0.014, Appendix 6)

11.6.4 Analysis of results by wind direction

Wind speed and direction are likely to change water circulation patterns within the production area. However, the nearest wind station for which records were available was Tiree, approximately 75 km to the south-west of the fishery. Given the differences in local topography and distance between the two it is likely that the overall patterns of wind direction differ, and that the wind strength and direction may differ significantly at any given time. Therefore it was not considered appropriate to compare *E. coli* results at Loch Ailort with wind readings taken at Tiree.

11.6.5 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence, and hence freshwater borne contamination at the site. Figure 11.28, 11.29 and 11.30 present scatter plots of *E. coli* result against salinity for mussels from Site 1 – Muckairn mussels, Pacific oysters from Camus Driseach and Native oysters from Camus Driseach respectively.

Mussels

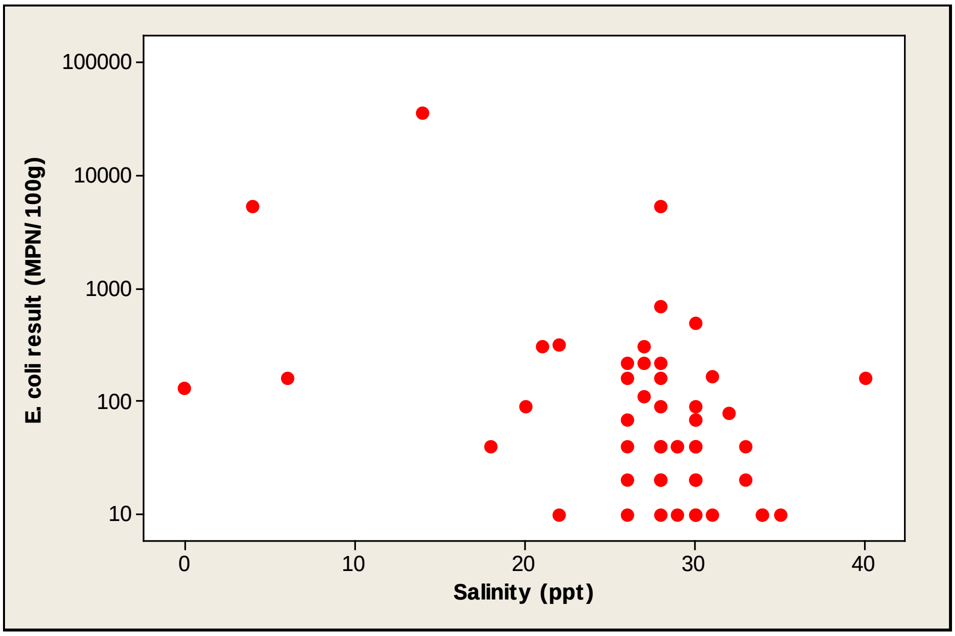

Figure 11.28 Scatterplot of result by salinity (mussels from Site 1 – Muckairn Mussels)

The coefficient of determination indicates that there was a negative relationship between the *E. coli* result for mussels from Site 1 – Muckairn Mussels and salinity (Adjusted R-sq=19.0%, p=0.001, Appendix 6).

Pacific oysters

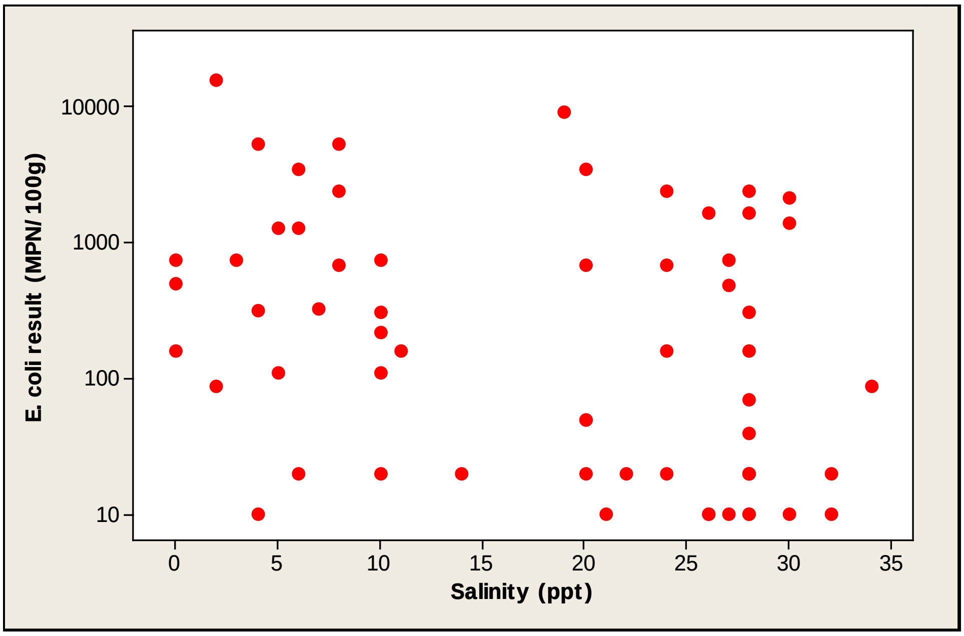

Figure 11.29 Scatterplot of result by salinity (Pacific oysters from Camus Driseach)

The coefficient of determination indicates that there was a weak negative relationship between the *E. coli* result for Pacific oysters from Camus Driseach and salinity (Adjusted R-sq=10.5%, p=0.006, Appendix 6).

Native oysters

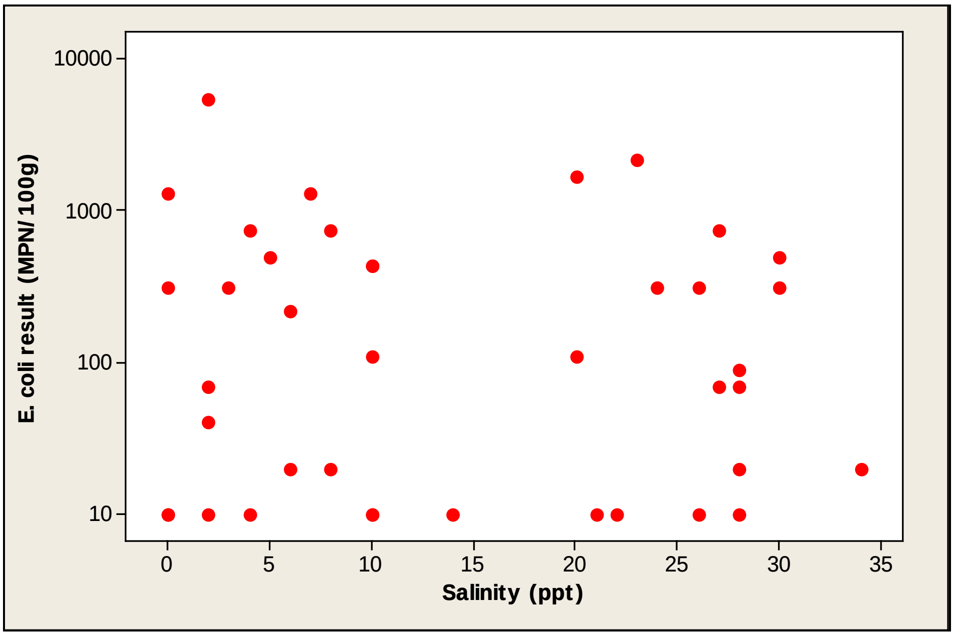

Figure 11.30 Scatterplot of result by salinity (Native oysters from Camus Driseach)

The coefficient of determination indicates that there was no relationship between the *E. coli* result for Native oysters from Camus Driseach and salinity (Adjusted R-sq=0.0%, p=0.748, Appendix 6).

11.7 Evaluation of peak results

Details of samples with results of over 4600 *E. coli* MPN/100g are presented in Tables 11.2, 11.3 and 11.4 for mussels, Pacific oysters, and Native oysters respectively.

Table 11.2 Sample details where results of over 4600 *E. coli* MPN/100g were obtained for mussels.

Collection date	GridRef	*E. coli* (MPN/100g)	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tide (spring/neap)	Tide (high/ low)
21/06/2005	NM750822	>18000	4.9	45.5	*	14	Spring	Ebb
20/09/2005	NM750822	5400	29.7	88.4	*	4	Spring	Ebb
27/06/2006	NM750822	5400	0.0	57.3	13	28	Spring	Ebb

All samples in Table 11.2 were collected from NM 750 822 (the RMP) from which the majority of mussel samples were reported. Two were taken in June, and one in September, although water temperature was only recorded on one occasion. They were taken following a range of 2 day cumulative rainfalls, but following moderate to high 7 day cumulative rainfalls, and salinity was low on two of the three sampling occasions. All three samples were taken on an ebbing spring tide, and within a twelve month period.

Table 11.3 Sample details where results of over 4600 *E. coli* MPN/100g were obtained for Pacific oysters.

Collection date	Grid Reference	*E. coli* (MPN/100g)	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tide (spring/neap)	Tide (high/ low)
25/06/2002	NM763816	5400	*	*	11.5	8	Spring	Ebb
29/07/2003	NM763816	9100	5	47.2	*	*	Spring	Ebb
23/08/2005	NM763816	5400	24.2	59.9	*	4	Decreasing	High
20/09/2005	NM763816	16000	29.7	88.4	*	2	Spring	Ebb
28/08/2007	NM763816	9100	3.3	35.5	*	*	Spring	Low
19/08/2009	NM 76156 81727	9200	*	*	14	19	Spring	Low

Five of the six samples were taken from NM 763 816 (the Pacific oyster RMP) from which the vast majority of Pacific oyster samples were recorded as being taken. All were taken during the warmer months of the year (one in June, one in July, three in August and one in September), although water temperature was only recorded on two occasions. They were taken following a range of 2 day rainfalls, but following moderate to high 7 day rainfalls, and generally at low salinities.

Table 11.4 Sample details where results of over 4600 *E. coli* MPN/100g were obtained for native oysters.

Collection date	Site	GridRef	*E. coli* (MPN/ 100g)	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tide (spring/ neap)	Tide (high/ low)
17/08/2004	Eilean na Gualainn	NM724788	9100	15.9	31.4	*	20	Spring	Ebb
20/09/2005	Camus Driseach	NM763816	5400	29.7	88.4	*	2	Spring	Ebb

One sample was taken from each of the two native oyster sites. Both were taken during the warmer months (one in August, one in September), although water temperature was not recorded on either occasion. Both were taken following moderate to high rainfall, and at relatively low salinities in relation to the range recorded at each site. Both were taken on ebbing spring tides. The highest result occurred at Eilean na Gualainn.

11.8 Summary and conclusions

A total of five site/species combinations were sampled since the beginning of 2002. These were Site 1 – Muckairn mussels (61 samples, 2002-2009), Camus Driseach Pacific oysters (75 samples, 2002-2009), Camus Driseach native oysters (47 samples, 2003-2008), Eilean na Gualainn native oysters (12 samples, 2004-2005) and Outer razors (10 samples, 2004-2005). Sample numbers were too low to carry out the more detailed analyses of temporal, seasonal and environmental effects for the latter two sites, although these results were considered in the geographic evaluation of contamination levels.

For mussels, although samples were reported to originate from Muckairn Mussels, the reported sampling locations fell into two distinct geographic clusters, one of which aligned with the actual location of the site, the other with the nominal mussel RMP, which approximately aligns with the Eilean Dubh site. The latter cluster of samples was taken before the start of the official control samplers so it was not possible to verify which site they actually originated from, although it is believed they were taken from Site 1 – Muckairn mussels. Within the former cluster of samples, there was the impression of higher results towards the eastern end of the site. There was no statistically significant difference in results between these two clusters either in terms of mean result or the proportion of results exceeding 230 *E. coli*/100 g. For Pacific oysters, all samples were reported from one site, and the reported sampling locations all plotted in its approximate vicinity. The vast majority of samples were reported from the RMP, and no geographical patterns were apparent in the sampling results. Native oyster samples were taken from two sites. These were sampled on the same day, and hence under approximately the same environmental conditions, on a total of 10 occasions. A comparison of these results reveals that although the geometric mean result was higher for Camus Driseach than for Eilean nan Gualainn this difference was not statistically significant. For razors in the outer loch, sample numbers are low, as were levels of contamination: the highest result was obtained at the easternmost sampling location.

At Site 1 – Muckairn Mussels, the highest results occurred in 2005 and 2006, but aside from that no other time trends were apparent. No seasonal patterns were found in levels of contamination and there was no relationship with water temperature.

At Camus Driseach no overall trends were found in levels of contamination over the historical data set for either Pacific or native oysters. However, very strong seasonal patterns were observed for both species, with higher results during the warmer months of the year. A positive relationship between *E. coli* results and water temperature was found for Pacific oysters, but water temperature was not recorded on enough sampling occasions to investigate this relationship for native oysters.

For these three site/species combinations, the relationship was investigated between *E. coli* levels and rainfall in the previous 2 and 7 days. The only relationship found was a weak positive relationship between rainfall in the previous 7 days and levels of *E. coli* at Site 1- Muckairn Mussels. A comparison of *E. coli* results with salinity at this site showed a negative relationship. A weaker negative relationship between *E. coli* results and salinity was also found for Pacific oysters from Camus Driseach, but not for native oysters at this site.

Analyses of *E. coli* results across both the spring/neap and high/low tidal cycles were carried out for these three site/species combinations. The only relationship between results and tidal cycles was at Site 1 – Muckairn mussels, where there was a weak correlation with the spring/neap cycle, where it tentatively appeared results were higher on spring tides. The three highest results arose on an ebbing spring tide.

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

11.9 Sampling frequency

When a production area has held the same (non-seasonal) classification for 3 years, and the geometric mean of the results falls within a certain range it is recommended that the sampling frequency be decreased from monthly to bimonthly (EU Working Group on Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 2007). This is not appropriate for any of the currently classified species within this production area they hold seasonal classifications.

12. Designated Shellfish Growing Waters Data

Loch Ailort was designated as a shellfish growing water in 2008. Microbiological data obtained under the classification monitoring programme overseen by FSAS were shared with SEPA for use in meeting the monitoring requirements under the shellfish growing water programme. Therefore, these results have already been considered within the analysis in Section 11.

13. Rivers and streams

Loch Ailort receives runoff from a catchment area of 76 km^2 (Edwards & Sharples, 1986). The following rivers and streams were measured and sampled during the shoreline survey. These represent the largest freshwater inputs into the production area. The survey was undertaken under unusually wet conditions, and so the two largest rivers were too large to safely measure at the time, and a number of small and probably temporary watercourses were not sampled or measured. Locations and calculated loadings for these watercourses are presented in Figure 13.1. Where no measurements were taken, water sample results are presented instead. There are no gauging stations on any of the watercourses draining into Loch Ailort.

Table 13.1 River loadings for Loch Ailort

No.	Position	Width (m)	Depth (m)	Flow (m/s)	Discharge (m^3/d)	*E. coli* (cfu/100ml)	*E. coli* loading (cfu/day)
1	NM 75723 81274	0.42	0.27	0.496	4860	100	4.9×10^{9}
2	NM 75583 81226	0.52	0.2	0.615	5530	<100	$<5.5 \times 10^{9}$
3	NM 75460 81240	0.8	0.2	3.20	44200	<100	$<4.4 \times 10^{10}$
4	NM 74200 79861	8	0.25	1.04	179000	<100	$<1.8 \times 10^{11}$
5	NM 73832 79014	1.2	0.5	1.75	90900	100	9.1×10^{10}
6	NM 73473 78718	7	0.35	1.19	253000	<100	$<2.5 \times 10^{11}$
7	NM 71947 78514	*	*	*		<100	
8	NM 76513 81981	*	*	*		180	
9	NM 76413 81710	0.8	0.1	0.503	3480	5200	1.8×10^{11}
10	NM 69054 78030	1.9	0.2	2.85	93400	<100	$<9.3 \times 10^{10}$
11	NM 69725 78264	3.4	0.4	0.493	57900	100	5.8×10^{10}
12	NM 72290 80029	1.4	0.1	0.670	8100	<100	$<8.1 \times 10^{9}$
13	NM 71113 80441	4.2	0.33	1.11	132000	<100	$<1.3 \times 10^{11}$
14	NM 75271 82488	3.3	0.21	0.369	22100	<100	$<2.2 \times 10^{10}$
15	NM 76245 81520	0.5	0.04	2.93	5050	<100	$<5.1 \times 10^{9}$
16	NM 76313 81577	0.2	0.03	1.46	758	<100	$<7.6 \times 10^{8}$
17	NM 76348 81624	3.2	0.12	0.17	5640	<100	$<5.6 \times 10^{9}$

* Not possible to measure

Of most significance in terms of discharge volume is the River Ailort (8) which discharges at the head of the loch, just to the north of the Camus Driseach site. It was not possible to measure discharge safely at the time of survey, but this river was about 20 m in width, about 1 m in depth and flowing rapidly (in the order of 1 m/s) at the bridge, so a very approximate estimate of its discharge at the time would be 1,700,000 m^3/d. Therefore, a very approximate estimate of its loading at the time would be 3.1×10^{12} *E. coli* per day, at least 10 times greater than any other of the measured freshwater inputs. Although the loading was high, contamination was relatively dilute and may be expected to spread rapidly over a wide area upon entering the loch.

Of the other inputs, all but one had low levels of contamination (100 or <100 *E. coli* cfu/100ml). The one exception to this was a small stream discharging to the head of the loch just south of the Camus Driseach site which contained

5200 *E. coli* cfu/100ml. The loading contributed by this stream was 1.8 x 10^{11}. No consents to discharge sewage to this stream were identified by SEPA, but it does flow through Inverailort so it is possible it receives some septic input. The sheep observed at Inverailort may also have contributed to contamination in this stream. Given the high levels of contamination within this watercourse, it is likely that it will impact on local water quality where it enters the loch.

Overall, freshwater inputs are likely to be a significant influence on water quality and hydrography in Loch Ailort as a whole, particularly in the upper basin of the loch. The River Ailort was the largest source in terms of discharge and overall loading. There were more and larger freshwater inputs on the south shore in comparison to the north shore. Levels of contamination were low and discharge high at time of survey. Low levels of contamination were not unexpected as these watercourses mainly drain hills and there were little or no identified livestock or sewage inputs to most.

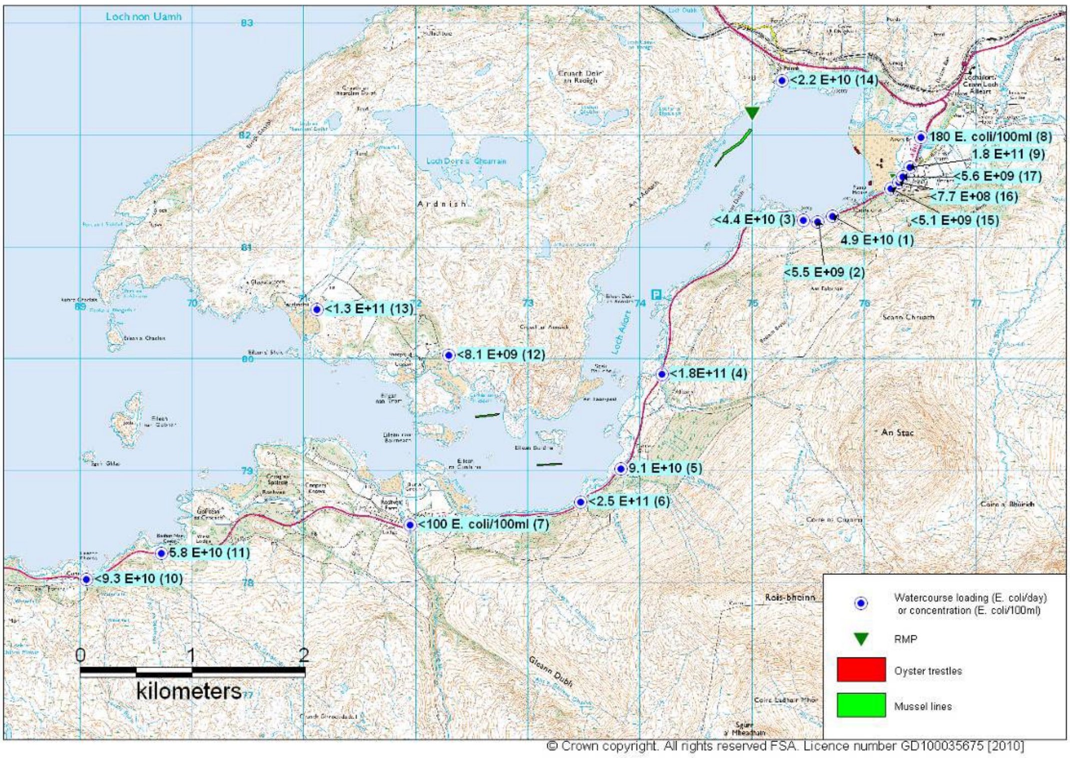

Figure 13.1 Stream loadings

14. Bathymetry and Hydrodynamics

Currents in coastal waters and estuaries are driven by a combination of tide, wind and freshwater inputs. This section aims to make a simple assessment of water movements around the area. Figure 14.1 shows the OS map of Loch Ailort and Figure 14.2 shows the bathymetry of the loch. The loch is 8.1 km long. Through most of its length it is between 0.5 and 1 km wide. The Scottish Sea Lochs catalogue identifies three sills and three basins within the loch. Figure 14.2 shows that there is a deep basin towards the head of the loch (maximum depth 43 m; Edwards & Sharples, 1986) and a small shallower basin (14 m) in the middle of the loch. The third basin (23 m deep) appears on Figure 14.2 almost as an extension of the upper one. The rest is relatively shallow. There are numerous islands in the middle loch and others at the mouth. There is an intertidal area at the head of the loch and smaller ones at the edges in the middle loch and associated with some of the islands.

The two maps show that the oyster trestles are located on the intertidal area of sand and shingle at the head of the loch. The bathymetry map shows that one set of mussel lines is located in 10 to 20 m of water in the inner loch, while the other two sets are located in the middle section of the loch, one in approximately 5 m of water and the other in 5 to 10 m.

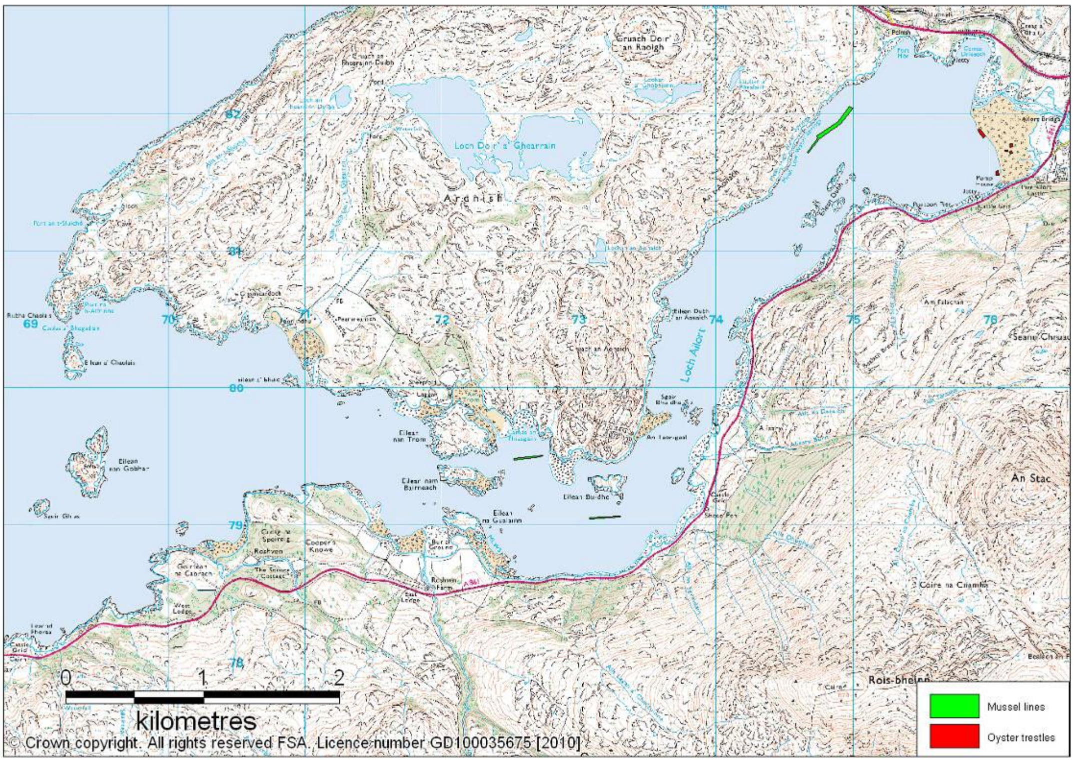

Figure 14.1 OS map of Loch Ailort

Figure 14.2 Bathymetry of Loch Ailort

14.1 Tidal Curve and Description

The two tidal curves below are for Loch Moidart to the south-west of Loch Ailort. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 GMT on 03/11/09 and the second is for seven days beginning 00.00 GMT on 10/11/09. This two-week period covers the date of the shoreline survey. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle.

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

0355 Loch Moidart is a Secondary Non-Harmonic port.
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

The tidal range at spring tide is therefore approximately 4.3 m and at neap tide 1.9 m.

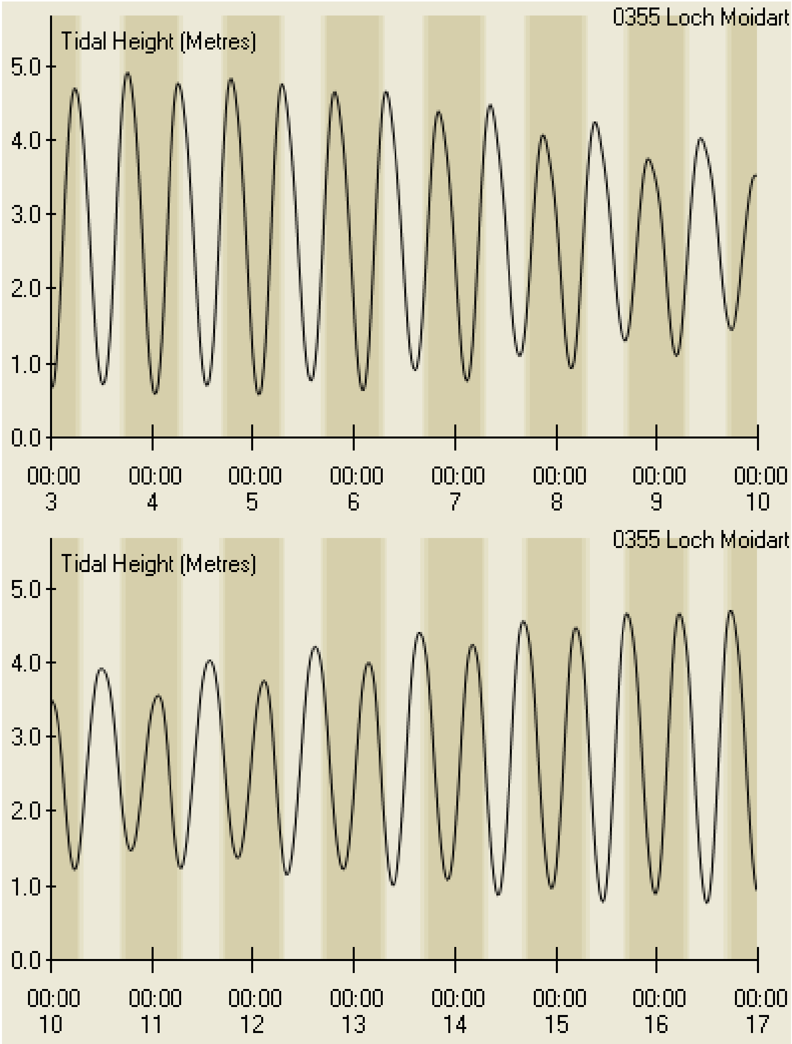

Figure 14.3 Tidal curves for Loch Moidart

14.2 Currents

No tidal stream information was available from TotalTide for the vicinity of Loch Ailort. The Clyde Cruising Club Sailing Directions for Ardnamurchan to Cape Wrath identifies that tidal streams are strong in the entrance to the loch. The Scottish Sea Loch Catalogue gives the current at the three sills as:

Outer sill	0.37 m/s
Middle sill	0.21 m/s
Inner sill	0.10 m/s

These currents relate to spring tides but are based on calculation rather than measurement. They are all very low – the currents in the basins would be expected to be lower still. There are two additional effects that could add to or otherwise modify these currents, one is density driven flows as a result of stratification, and the other is wind-driven flows. Gillibrand *et al*. (1996) determined that there was significant stratification in the inner loch. Surface salinities were 5 ppt at the head of the loch, increasing to a value of 32 ppt towards the mouth of the loch. In the inner basin, salinities ranged from 5-21 ppt at the surface, and >32 ppt at depth.

Gillibrand *et al*. (1996) recorded the current at a single location in the main basin above the inner sill over two periods of several months in 1992/1993. Measurements were made at three depths, 3 m, 10 m and 28 m. They resolved the recorded data into components. The mean along-loch component towards the head of the loch was 0.0119, 0.0091 and 0.0022 m/s respectively at the three depths. Maximum flows recorded at spring tides over most of the monitoring periods were 0.20, 0.10-0.15 and <0.05 m/s respectively. Return currents were not detected but this could have been due to the location of monitoring. Deepwater currents occurred over one period of a few days and this was ascribed to a deepwater flushing event. It was inferred that the mean, (rather than tidal) currents were the result of the predominant winds blowing up the loch.

14.3 Conclusions

Contamination in the inner part of the loch will tend to be confined to the upper 5 – 10 m depth due to stratification. Although tidal currents within the loch are relatively weak, they still appear to predominate with the residual current being due to wind effects. The general transport of contamination will be along the loch, in the direction of tidal flows. The oyster trestles especially, in the intertidal area at the head of the loch, will be subject to contamination arising from the freshwater sources at the head as the tide falls. Outside of the intertidal areas, the maximum distance travelled over the course of an ebbing or flooding tide, at springs, would be less than 5 km (not taking into account dilution and dispersion effects). Given the surface layer, and depth of the sills, the sills themselves may not provide a significant barrier to transport of contamination between the upper parts of the basins. The numerous islands will complicate the currents, and thus transport of contaminants, in their immediate vicinity.

15. Shoreline Survey Overview

The shoreline survey was conducted on the 3rd to 5th November 2009 following a period of very high rainfall.

There were three mussel sites and one Pacific oyster site within the production area. The mussel sites were all longline sites, with mussels reported to take about 3 years to reach maturity in the loch. Two of these had stock on site of various sizes (Site 1 – Muckairn Mussels and Eilean Dubh). The third mussel site (Eilean Buidhe) was still in construction at the time of survey. This was due to be completed to catch the spatfall in spring 2010. The Pacific oyster site (Camus Driseach) was located in the intertidal area at the head of the loch. Here, Pacific oysters were cultured on trestles, taking about 5-7 years to reach market size.

Population on the shores of Loch Ailort was low and centred around the small settlements of Inverailort and Roshven. Two wastewater discharge pipes were recorded at Inverailort near the southern end of the trestles. In addition to these another septic discharge was seen at the Marine Harvest building on the south shore, and another two septic tank discharges from individual private houses were observed just to the west of Roshven, again on the south shore. Other properties in the area are likely to be served by septic tanks discharging to soakaway or possibly watercourses. The area receives significant numbers of visitors mainly during the summer months. There was a hotel at Lochailort, and some houses in the area are holiday homes. A bothy on the north shore of the outer loch was in use at the time of survey. A number of caravans were seen along the south shore of the loch, towards its western end. Forsay caravan site hosted about 25 static caravans, a few of which appeared to be in occupation at the time. It is unclear whether these were holiday homes, more permanent accommodation, or a mixture of the two. Also, 5 caravans were seen in a layby close to this site, some of which were occupied.

Boating traffic was limited to a few small craft. Seven dinghies and small yachts were recorded on moorings just to the east of Roshven. There was an active fish farm just off the south shore towards the head of the loch, with frequent small boat traffic between its land base on the adjacent shore and the cages. Two yachts and one RIB were seen on moorings in this area.

The surrounding land rises steeply to a high altitude in most places, and is mostly rough moorland, with some areas of birch woods along the coastal strip on the south shore. Little in the way of livestock was observed in the area. An area of pasture were seen by Inverailort Castle, where about 30 sheep were present. These sheep are also grazed on the area of salt grass at the head of the loch where they have unrestricted access to the foreshore by the oyster trestles. Additionally, four horses and a handful of chickens were seen at Roshven, and 9 sheep were seen on the road on the south shore of the outer loch. The area hosts a significant population of red deer, with four seen during the shoreline survey. Four seals were recorded, so it is likely that seals come into close proximity of the fishery sites from time to time. Small numbers of geese were recorded on the salt grass at the head of the loch and at Roshven. A few seabirds such as cormorants and gulls were seen in various places, but not in great numbers.

Major freshwater inputs to the loch were sampled and their discharge measured. Exceptionally heavy rainfall had preceded the survey, and the River Ailort and Irine Burn at Roshven were too large to measure. Most of these watercourses had very low levels of *E. coli* at the time (100 or <100 cfu/100ml). The two exceptions were the River Ailort which contained 180 *E. coli* cfu/100ml, and a small stream discharging to the head of the loch just south of the Camus Driseach site which contained 5200 *E. coli* cfu/100ml, probably as a consequence of either sewage or livestock related inputs.

Seawater samples generally contained moderate levels of *E. coli* (22-210 cfu/100ml), although one sample taken by the end of a private sewer outfall at the head of the loch contained 1600 cfu/100ml, presumably due to the discharge. The two highest results both arose amongst the trestles at the Camus Driseach site (1600 and 210 *E. coli* cfu/100ml). Of the five seawater samples taken at the mussel lines, the two highest results arose at Eilean Dubh (45 and 47 *E. coli* cfu/100ml), the sample taken at Eilien Buidhe contained 39 *E. coli* cfu/100ml, and the two lowest results arose at Site 1 – Muckairn mussels (22 and 26 *E. coli* cfu/100ml). Salinities were markedly lower in the upper basin of the loch (range: 0.8 – 4.8 ppt) compared to those in the outer basins (range: 18.4 – 28.9 ppt). Salinity profiles showed stratification at all three of the mussel sites, with a layer of fresher water in the top 2.5 m. This was most marked at the site within the inner basin (Eilean Dubh) where surface salinity was 1.7 ppt. Surface salinities were 20.4 ppt at Site 1 – Muckairn mussels, and 17.4 ppt at Eilean Buidhe.

Two Pacific oyster samples were taken from Camus Driseach, with the one from the north west end of the site containing 260 *E. coli* MPN/100g, and the one taken from the south east end of the site contained 330 *E. coli* MPN/100 g. Mussel samples were taken from both ends of Site 1 – Muckairn mussels and Eiliean Dubh from the top and bottom of the lines. At all locations results were higher in the sample taken from the top of the lines. Results were higher on average at the Eilean Dubh site. At Eilean Dubh, results were higher at the eastern end of the site, and at Site 1 – Muckairn mussels, results were very similar at the two ends of the lines.

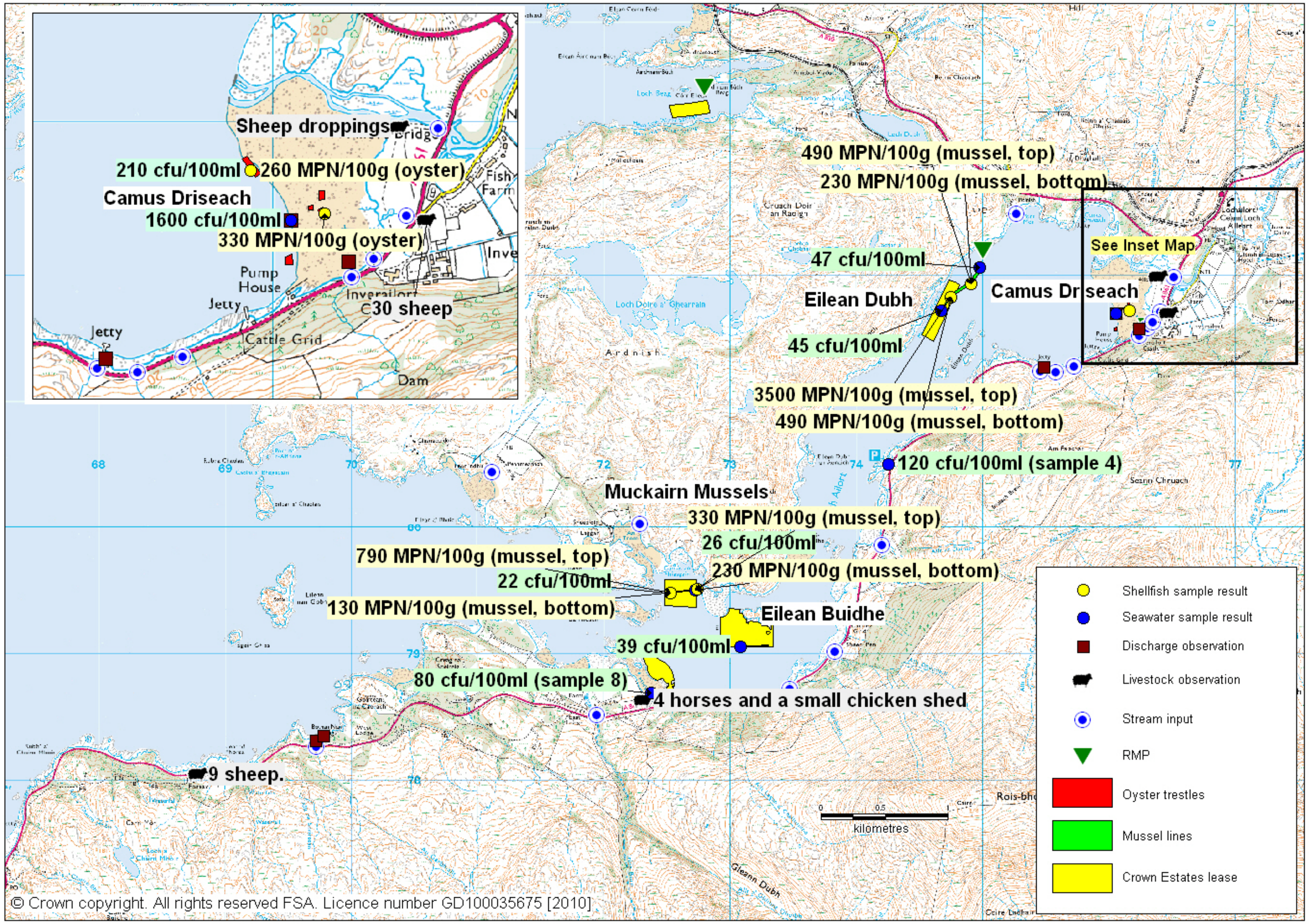

Figure 15.2 Summary of shoreline observations

16. Overall Assessment

Human sewage impacts

Population on the shores of Loch Ailort is low, and centred around the small community of Lochailort/Inverailort at the head of the loch, and the small settlement of Roshven on the south shore. At Lochailort/Inverailort there are 5 consented discharges to watercourses with a total population equivalent of 38, with two additional private discharges to Loch Ailort at the south end of the Camus Driseach site, and a further private discharge from the Marine Harvest site just to the west of Inverailort noted during the shoreline survey. At Roshven there are 3 consented discharges to watercourses with a total population equivalent of 11, with a further private septic tank discharge to a watercourse here recorded during the shoreline survey. The two discharges to the intertidal area at Camus Driseach are likely to impact on water quality at this site. Although the estimate of the *E. coli* loading from the River Ailort at the time of shoreline survey was much higher than what might be expected from the two small private discharges, contamination from the discharges is much more concentrated, and so they are likely to cause greater local deterioration in their immediate vicinity than will the river. Other discharges are likely to cause similar deteriorations in their immediate vicinity, and contribute to overall levels of contamination within the area. Overall impacts from these discharges may be slightly greater in the upper basin as they are most concentrated at Lochailort/Inverailort.

Boating traffic within the loch is light, and at the time of shoreline survey was limited to a handful of small craft seen between Roshven and Inverailort, including a few moored small yachts. Of these vessels, any occupied yachts may discharge overboard. although It is uncertain whether any of those seen were occupied and none was particularly close to any of the fisheries.

Agricultural impacts

The surrounding land rises steeply to a high altitude in most places, and is mostly rough moorland, with some areas of birch woods along the coastal strip on the south shore, and almost no pastureland. Agricultural census data indicates that livestock kept within the Arisaig and Moidart parish is primarily a mixture of sheep and cattle at low average densities. Little livestock was observed during the shoreline survey. Of most significance to the fisheries were about 30 sheep kept at Inverailort, and often grazed on the area of salt grass at the head of the loch where they have unrestricted access to the foreshore by the oyster trestles. This creates significant potential for contamination by livestock at the Camus Driseach site, and may also make a significant contribution to levels of contamination found in the upper basin of the loch. The sheep may also affect water quality at Eilean Dubh.

The only other livestock recorded during the shoreline survey were 4 horses and a chicken shed recorded at Roshven, and a group of 9 sheep recorded on the road on the south shore of the outer loch. Due to the low number of animals, and the distance from the fisheries, it is unlikely that these have a significant impact.

Wildlife impacts

The main wildlife species potentially impacting on the production areas are deer, seals, seabirds and geese. Contamination from deer will be carried into the production area by streams draining the surrounding hills and this will occur all year round. Seals are likely to be a minor year round presence. Impacts from seabirds may be higher at Eiliean Dubh, as they are reported to breed on the rocky islands just south of this site. Geese will tend to be found on areas of pasture, and there may be greater numbers present in the winter months if they overwinter in the area. However, as all these species are highly mobile, the impacts of these on the fishery will be unpredictable, and deposition of faeces by wildlife is likely to be widely distributed around the area.

Seasonal variation

The area receives a small number of visitors, mainly during the summer months. There is a hotel at Lochailort, and some houses in the area are holiday homes, and there is a static caravan park at Forsay on the south shore. Therefore, human population in the area is likely to be higher during the summer. Sheep numbers are also likely to be higher in the summer, so inputs from livestock may be higher during the summer.

Weather is wetter and windier during the autumn and winter months, so in general more rainfall dependent contamination such as runoff from pastures may be expected during these times. However, heavy rainfall events can occur at any time of the year and may be of greater impact during the summer months as livestock numbers are higher, and there are likely to be longer dry periods during which faecal matter can build up on pastures leading to a highly contaminated ‘first flush’ of runoff.

An analysis of historic *E. coli* monitoring data showed a very strong seasonal effect in Pacific and native oysters at Camus Driseach, with higher results occurring during the warmer months of the year. No significant seasonal effect was found for mussels from Site 1 – Muckairn Mussels.

Rivers and streams

Loch Ailort receives runoff from a catchment area of approximately 76 km^2, which is mainly moorland. Bacterial loadings of significant freshwater inputs to the loch were calculated, where possible, from measurements taken during the shoreline survey, which was undertaken during the autumn following very heavy rainfall. *E. coli* levels in the streams measured were generally low, containing from <100 to 180 cfu/100 ml. Low levels of contamination were not unexpected as these watercourses mainly drain hills, with little or nothing in terms of livestock or sewage inputs to most. The one exception to this was a very small stream discharging to the head of the loch just south of the Camus Driseach site which contained 5200 *E. coli* cfu/100ml, possibly as a consequence of either sewage or livestock related inputs.

The largest freshwater input is the River Ailort, which discharges to the head of the loch. A water sample from this river contained 180 *E. coli* cfu/100ml, but it was not possible to safely measure this stream during the shoreline survey. A rough visual estimate of its discharge was used to calculate an approximate *E. coli* loading, which was at least 10 times greater than any other of the measured freshwater inputs. Impacts of this source are likely to be higher on the shellfish sites closer to the head of the loch. There were more and larger freshwater inputs on the south shore in comparison to north shore.

Meteorology, hydrology, and movement of contaminants

Although tidal currents within the loch are relatively weak, they still appear to predominate with a residual current being due to wind effects. The general transport of contamination will be up and down the loch as the tide floods and ebbs. The maximum distance travelled over the course of an ebbing or flooding tide, at springs, would be less than 5 km (not taking into account dilution and dispersion effects). A weak correlation was found between historic *E. coli* monitoring results and the spring/neap cycle for mussels from Site 1 – Muckairn mussels, where results were generally higher on increasing and spring tides. No relationship was found between the spring/neap tidal cycle and historic *E. coli* monitoring results for either Pacific or Native oysters at the Camus Driseach site.

Contamination in the upper part of the loch will tend to be confined to the upper 5 – 10 m depth due to stratification. Salinities of surface water samples taken during the shoreline survey were markedly lower in the upper basin of the loch compared to those taken in the outer basins. Salinity profiles showed stratification at all three of the longline mussel sites, with a layer of fresher water in the top 2.5 m. Stratification was much more marked at the mussel site within the upper basin (Eilean Dubh). Surface salinity was slightly lower at the Eilean Buidhe than at Site 1 – Muckairn mussels. This suggests that levels of freshwater borne contamination will be higher in the surface layer of the inner basin than in the outer basins, probably with marked changes across the sills where mixing will occur. A negative relationship was found between salinity and historic *E. coli* monitoring results for mussels from Site 1 – Muckairn mussels suggesting that significant sources of contamination to this site are freshwater borne. A weaker negative relationship was found between salinity and historic *E. coli* monitoring results for Pacific oysters (but not native oysters) at Camus Driseach. Any relationship between salinity and levels of contamination at this site may have been masked by the tendency for oysters to stop feeding and hence accumulating contamination during periods of very low salinity frequently experienced at this location. For these three site/species combinations, the relationship was investigated between historic *E. coli* monitoring results and rainfall in the previous 2 and 7 days. A weak positive relationship between rainfall in the previous 7 days and levels of *E.*

coli at Site 1 - Muckairn mussels only. This is consistent with the relationships between historic *E. coli* monitoring results and salinity.

Wind is likely to affect circulation patterns within the loch at times, driving a surface current in the same direction as the wind. Wind effects are likely to be more dynamic than tidal or freshwater effects, changing rapidly with wind speed and direction. Due to the distance between the fishery and the nearest weather station for which wind data was available no evaluation of the effects of wind on historic *E. coli* monitoring results was attempted. A south-westerly wind will result in increased wave action at the Camus Driseach site at the head of the loch, which may resuspend any organic matter settled in the substrate.

Temporal and geographical patterns of sampling results

A total of five site/species combinations were sampled for classification monitoring since the beginning of 2002. At Site 1 – Muckairn mussels the highest results occurred in 2005 and 2006. At Camus Driseach no overall temporal trends were found in levels of contamination for either Pacific or native oysters. There was insufficient data to evaluate overall temporal trends for the other two site/species combinations.

Although all historic mussel samples from the classification programme were reported to originate from Site 1 – Muckairn Mussels, they fell in two distinct geographic clusters, one of which aligned with the sites actual location, the other at the nominal mussel RMP, which approximately aligns with the Eilean Dubh site. The latter cluster of samples was taken before the start of the official control samplers so it was not possible to verify which site they actually originated from, although it is believed that these samples were all taken from Site 1 – Muckairn mussels. Within the former cluster of samples, there was the impression of higher results at the eastern end of the site. There was no statistically significant difference in results between these two clusters either in terms of mean result or the proportion of class A results. Mussel samples were taken from Site 1 – Muckairn mussels and Eilean Dubh during the shoreline survey, and levels of contamination were consistently higher at the Eilean Dubh site, and higher in samples taken from the top of the water column at both sites. Within these two sites, results were higher at the western end of the site Eilean Duch, and at Site 1 – Muckairn mussels results were very similar at the two ends of the lines. Of the five water samples taken at the mussel lines during the shoreline survey, the two highest results arose at Eilean Dubh, and the two lowest results arose at Site 1 – Muckairn mussels, with an intermediate result at Eilean Buidhe.

For Pacific oysters at Camus Driseach, no geographical patterns were apparent in the historic *E. coli* monitoring results. Two Pacific oyster samples were taken from different locations within this site during the shoreline survey, and both contained very similar levels of *E. coli* (260 and 330 MPN/100g), with the marginally higher result arising at the south east end of the site. The two highest shoreline survey seawater sample results were for samples taken at Camus Driseach.

Historic *E. coli* monitoring samples of native oysters were taken from two sites, which were sampled on the same day and hence under the same environmental conditions on a total of 10 occasions. A comparison of these results reveals that the geometric mean result was slightly higher for Camus Driseach than for Eilean nan Gualainn, but this difference was not statistically significant.

For razors in the outer loch, historic *E. coli* monitoring sample numbers were low, as were levels of contamination: the highest E. coli result was obtained from the easternmost sampling point.

Taken together, these sampling results indicate that levels of contamination are highest at the head of the loch, and decline noticeably towards its mouth.

Conclusions

The most significant identified sources of contamination by freshwater inputs, sewage discharges and livestock are at the head of the loch, in the vicinity of the Camus Driseach site. Sampling results generally indicated a gradient in levels of contamination, which decrease from the head to the mouth of the loch, although it is possible that there are other small areas of lower water quality, for example near the private discharges at Roshven.

The Eilean Dubh mussel site is located in the upper (first) basin of the loch, and Site 1 Muckairn mussels and Eilean Buidhe are both located in the third basin. The upper basin has greater freshwater influence and levels of contamination than found in outer basins, and shoreline survey sampling results also showed markedly higher levels of contamination at Eilean Dubh site compared to Site 1 – Muckairn mussels. Therefore Eilean Dubh should be classified separately from the other two mussel sites.

Significant stratification occurs within the loch at times, and the surface layer of fresher water is likely to be more contaminated than the saline water below. Samples taken during the shoreline survey strongly supported this supposition.

Highly significant seasonality was found in historic *E. coli* monitoring results for oysters at Camus Driseach, and some potential seasonality in contamination sources was identified. Both mussels and Pacific oysters currently hold seasonal classifications and therefore a stability assessment to determine whether a lower sampling frequency was appropriate was not undertaken.

17. Recommendations

Loch Ailort (Camus Driseach) Pacific Oysters – Loch Ailort 2

Production area
Recommended production area boundaries are an area bounded by lines drawn between NM 7629 8185 to NM 7605 8147 to NM 7580 8200 to NM 7620 8200 to NM 7634 8193 extending to MHWS.

The recommended area covers the current oyster fishery but excludes an area in the immediate vicinity of Inverailort castle discharge, which is believed to contain raw sewage. There were no trestles within 100 m of this discharge at the time of the shoreline survey. It also excludes the part of the shore nearest the discharge of the River Ailort.

RMP
It is recommended that the RMP be relocated to NM 7616 8172. This will detect the contamination from the various sources in the area and will specifically detect any contamination arising from a small private discharging to just below MLWS: this was within 60 m of the nearest trestles at the time of the shoreline survey. It should also reflect the influence of a nearby small, but heavily contaminated stream.

Tolerance
A sampling tolerance of 10 m is recommended.

Depth
Specification of sampling depth is not applicable.

Frequency
This should be monthly as a stability assessment to support a reduced frequency was not applicable.

The relative positions of the recommended production area boundaries and RMP for Loch Ailort: Camus Driseach are shown mapped in Figure 17.1.

Loch Ailort (Eilean Dubh) Mussels – Loch Ailort

Production area
Recommended production area boundaries are lines drawn between NM 7516 8234 and NM 7516 8139 and between NM 7350 7980 and NM 7399 7984 extending to MHWS. This excludes the area around the head of the loch where the most significant sources of contamination are located.

RMP
It is recommended the RMP be relocated to NM 7498 8204 as the main sources of contamination lie to the east of the site.

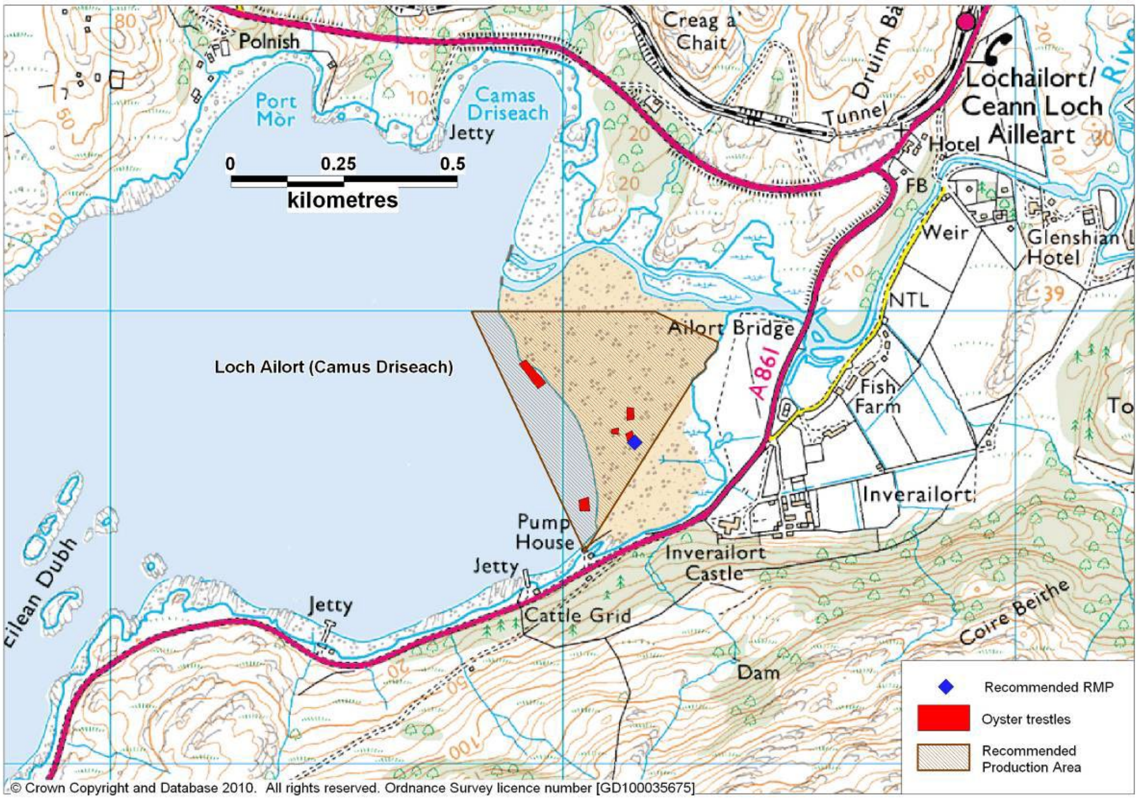

Figure 17.1 Recommendations for Pacific oysters at Loch Ailort

Tolerance
A sampling tolerance of 20 m is recommended. This allows for some variation in accessing animals of sufficient size and drift of the lines themselves. If either of these factors presents a problem with regard to sampling within the recommended tolerance, consideration should be given to placing a bag of shellfish at the recommended location and depth specifically for sampling purposes. Shellfish should be placed in situ for at least two weeks prior to sampling to ensure that they have taken on the microbiological quality of the RMP.

Depth
The recommended depth for sampling is at 1 m given that significant stratification occurs within the loch.

Frequency
This should be monthly as a stability assessment to support a reduced frequency was not applicable.

The relative positions of the recommended production area boundaries and RMP for Loch Ailort: Eilean Dubh are shown mapped in Figure 17.2.

Loch Ailort (mid) Mussels – Loch Ailort 1

Production area
Recommended production area boundaries are lines drawn between NM 7350 7980 and NM 7399 7984 and between NM 7253 7971 and NM 7233 7953 and between NM 7233 7953 and NM 7281 7863 extending to MHWS. This encompasses both of the farmed mussels sites at Site 1 – Muckairn Mussels and Eilean Buidhe site, running from the sill located east of the fisheries while excluding the potential sources of contamination at Roshven.

RMP
It is recommended the RMP be relocated to NM 7329 7906. This is at the easternmost end of the Eilean Buidhe site and therefore closest to the sources of pollution at the head of the loch. No stock was present on this site at the time of shoreline survey and therefore a dedicated sampling bag will need to be established at the recommended location and depth. Shellfish should be placed in situ for at least two weeks prior to sampling to ensure that they have taken on the microbiological quality of the RMP.

Tolerance
A sampling tolerance of 20 m is recommended. This allows for drift of the lines themselves and, when stock is present, some variation in accessing animals of sufficient size.

Depth
The recommended depth for sampling is at 1 m given that significant stratification occurs within the loch.

Frequency
This should be monthly as a stability assessment to support a reduced frequency was not applicable.

The relative positions of the recommended production area boundaries and RMP for Loch Eilort: Mid are shown mapped in Figure 17.2.

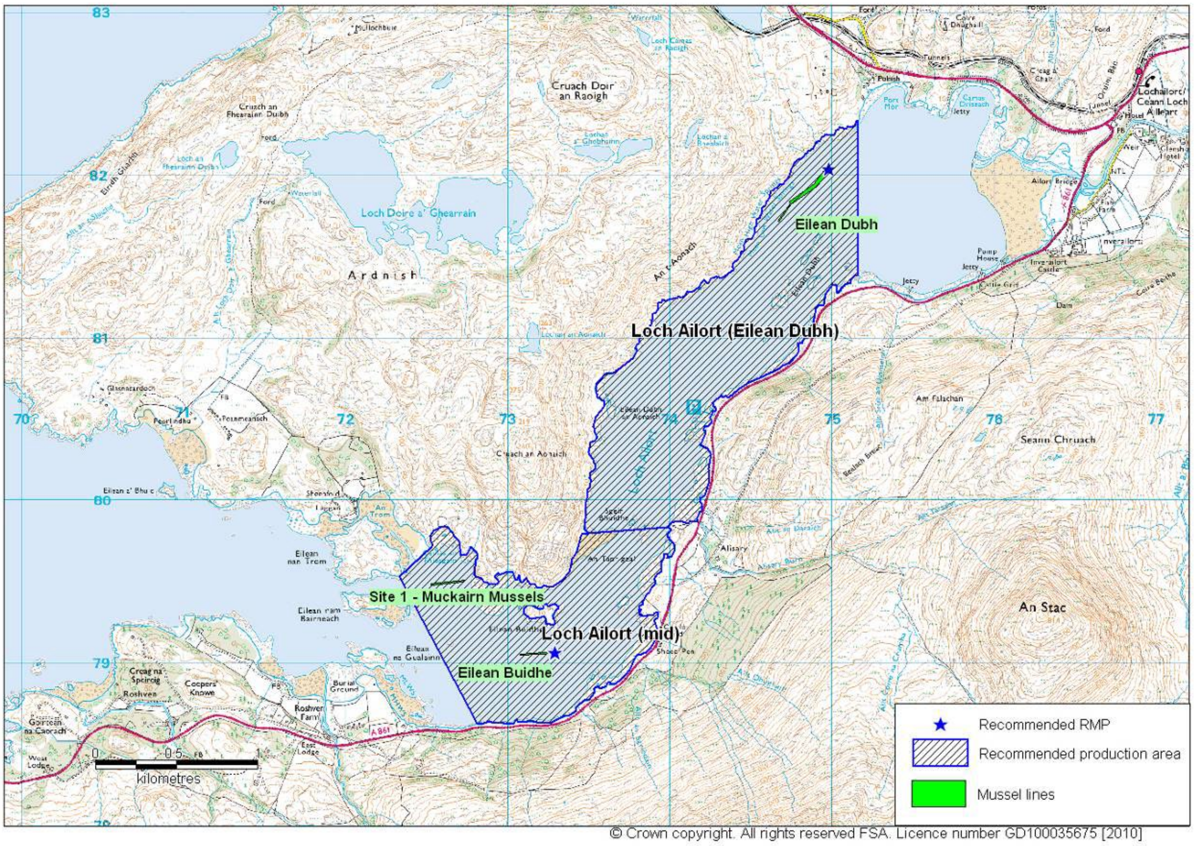

Figure 17.2 Recommendations for mussels at Loch Ailort

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Sampling Plan for Loch Ailort

PRODUC-TION AREA	SITE NAME	SIN	SPECIES	TYPE OF FISH-ERY	NGR OF RMP	EAST	NORTH	TOLER-ANCE (M)	DEPTH (M)	METHOD OF SAMPLING	FREQ OF SAMPLING	LOCAL AUTHORITY	AUTHORISED SAMPLER(S)	LOCAL AUTHORITY LIAISON OFFICER
Loch Ailort 2	Camus Driseach	HL 114 207 13	Pacific oyster	Trestle	NM 7616 8172	176160	781720	10	N/A	Hand	Monthly	Highland Council (Lochaber)	Stephen Lewis	Stephen Lewis
Loch Ailort	Eilean Dubh	HL 114 937 08	Common mussel	Line	NM 7498 8204	174980	782040	10	<1m	Hand	Monthly	Highland Council (Lochaber)	Stephen Lewis	Stephen Lewis
Loch Ailort 1	Site 1 – Muckairn mussels, Eilean Buidhe	HL 114 214 08, HL 114 209 08	Common mussel	Line	NM 7329 7906	173290	779060	10	<1m	Hand	Monthly	Highland Council (Lochaber)	Stephen Lewis	Stephen Lewis

Table of Proposed Boundaries and RMPs – Loch Ailort

Production Area	Species	SIN	Existing Boundary	Existing RMP	New Boundary	New RMP	Comments
Loch Ailort 2	Pacific oyster	HL 114 207 13	Line drawn between NM 6800 7825 and NM 6912 8069 extending to MHWS	NM 763 816	Area bounded by lines drawn between NM 7629 8185 to NM 7605 8147 to NM 7580 8200 to NM 7620 8200 to NM 7634 8193 extending to MHWS	NM 7616 8172	Area reduced to exclude areas around raw discharge and near river, RMP moved to trestle nearest contaminated stream.
Loch Ailort	Common mussel	HL 114 937 08	Line drawn between NM 6800 7825 and NM 6912 8069 extending to MHWS	NM 750 822	Area bounded by lines drawn between NM 7516 8234 and NM 7516 8139 and between NM 7350 7980 and NM 7399 7984 extending to MHWS	NM 7498 8204	Area split, and further reduced to exclude head of loch. New RMP recommended at Eilean Dubh site
Loch Ailort 1	Common mussel	HL 114 214 08, HL 114 209 08	Line drawn between NM 6800 7825 and NM 6912 8069 extending to MHWS	NM 750 822	Area bounded by lines drawn between NM 7350 7980 and NM 7399 7984 and between NM 7253 7971 and NM 7233 7953 and between NM 7233 7953 and NM 7281 7863 extending to MHWS	NM 7329 7906	Area split, and further reduced to exclude outer loch and Roshven. New RMP recommended at Eilean Buidhe site.

Geology and Soils Information

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

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

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

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

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

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

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

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

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

Glossary of Soil Terminology

Calcareous: Containing free calcium carbonate.

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

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

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

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

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General Information on Wildlife Impacts

Pinnipeds

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

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

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

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

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

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

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

Cetaceans

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

A variety of cetacean species are routinely observed 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.

Table 1 Cetacean sightings in 2007 – Western Scotland.

Common name	**Scientific name**	**No. sighted***
Minke whale	*Balaenoptera acutorostrata*	28
Killer whale	*Orcinus orca*	183
Long finned pilot whale	*Globicephala melas*	14
Bottlenose dolphin	*Tursiops truncatus*	369
Risso's dolphin	*Grampus griseus*	145
Common dolphin	*Delphinus delphis*	6
Harbour porpoise	*Phocoena phocoena*	>500

*Numbers sighted are based on rough estimates based on reports received from various observers and whale watch groups. Source: Hebridean Whale and Dolphin Trust.

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.

Otters

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

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

References:

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

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

Tables of Typical Faecal Bacteria Concentrations

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

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

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

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

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

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

Statistical data

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

Section 11.3 T-test comparison of mussel results by sampling location

```
Two-sample T for log Ecoli

cluster   N   Mean  StDev  SE Mean
N        51  1.856  0.764     0.11
S        10  1.528  0.469     0.15


Difference = mu (N) - mu (S)
Estimate for difference:  0.328
95% CI for difference:  (-0.055, 0.711)
T-Test of difference = 0 (vs not =): T-Value = 1.79  P-Value = 0.089  DF = 19
```

Section 11.3 Fisher's exact comparison of proportion of mussel results over 230 *E. coli* MPN/100g by sampling location

```
Using frequencies in No


Rows: res cat   Columns: Clus

         N   S  All

<230    42  10   52
>230     9   0    9
All     51  10   61

Cell Contents:      Count


Fisher's exact test: P-Value =  0.332391
```

Section 11.3 Paired T-test comparison of native oyster results by site

```
Paired T for Camus Driseach (log) - Eilean na Gualainn (log)

                           N   Mean  StDev  SE Mean
Camus Driseach (log)      10  1.621  0.682    0.216
Eilean na Gualainn (log)  10  1.470  0.643    0.203
Difference                10  0.152  0.819    0.259


95% CI for mean difference: (-0.435, 0.738)
T-Test of mean difference = 0 (vs not = 0): T-Value = 0.59  P-Value = 0.573
```

Section 11.5 One way ANOVA comparison of *E. coli* results by season (mussels from Site 1- Muckairn mussels)

```
Source  DF      SS     MS     F      P
Season   3   2.574  0.858  1.66  0.186
Error   57  29.474  0.517
Total   60  32.048

S = 0.7191   R-Sq = 8.03%   R-Sq(adj) = 3.19%


                           Individual 95% CIs For Mean Based on
```

```
                                 Pooled StDev
Level   N    Mean   StDev  -------+---------+---------+---------+--
1      17  1.6141  0.5502     (---------*---------)
2      21  2.0240  0.9140                  (--------*--------)
3      11  1.9403  0.7925            (-----------*------------)
4      12  1.5556  0.3862  (----------*-----------)
                           -------+---------+---------+---------+--
                                1.40      1.75      2.10      2.45

Pooled StDev = 0.7191
```

Section 11.5 One way ANOVA comparison of *E. coli* results by season (Pacific oysters from Camus Driseach)

```
Source  DF      SS      MS      F      P
Season   3  35.167  11.722  28.25  0.000
Error   71  29.457   0.415
Total   74  64.624

S = 0.6441   R-Sq = 54.42%   R-Sq(adj) = 52.49%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  -----+---------+---------+---------+----
1      22  1.8532  0.7746          (--*---)
2      19  3.2247  0.5907                            (---*---)
3      19  2.6533  0.6888                     (---*---)
4      15  1.3993  0.3814  (----*----)
                           -----+---------+---------+---------+----
                              1.40      2.10      2.80      3.50

Pooled StDev = 0.6441


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

Individual confidence level = 98.95%


Season = 1 subtracted from:

Season    Lower   Center   Upper  ------+---------+---------+---------+---
2        0.8409   1.3715  1.9021                      (--*---)
3        0.2695   0.8001  1.3308                  (--*---)
4       -1.0212  -0.4539  0.1134           (---*---)
                                  ------+---------+---------+---------+---
                                     -1.5       0.0       1.5       3.0


Season = 2 subtracted from:

Season    Lower   Center    Upper  ------+---------+---------+---------+---
3       -1.1211  -0.5714  -0.0217           (--*---)
4       -2.4106  -1.8254  -1.2402  (---*---)
                                   ------+---------+---------+---------+---
                                      -1.5       0.0       1.5       3.0


Season = 3 subtracted from:

Season    Lower   Center    Upper  ------+---------+---------+---------+---
4       -1.8392  -1.2540  -0.6688      (---*---)
                                   ------+---------+---------+---------+---
                                      -1.5       0.0       1.5       3.0
```

Section 11.5 One way ANOVA comparison of *E. coli* results by season (native oysters from Camus Driseach)

```
Source  DF      SS     MS      F      P
Season   3  12.800  4.267  10.06  0.000
Error   43  18.239  0.424
Total   46  31.040

S = 0.6513   R-Sq = 41.24%   R-Sq(adj) = 37.14%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  ---------+---------+---------+---------+
1      14  1.8439  0.6849            (----*----)
2       9  2.7958  0.3649                         (-----*-----)
3      15  2.2538  0.8556                  (----*----)
4       9  1.1942  0.3217  (-----*-----)
                           ---------+---------+---------+---------+
                                 1.40      2.10      2.80      3.50

Pooled StDev = 0.6513


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

Individual confidence level = 98.94%


Season = 1 subtracted from:

Season    Lower   Center   Upper  ------+---------+---------+---------+---
2        0.2082   0.9519  1.6957                 (----*----)
3       -0.2370   0.4099  1.0568              (----*---)
4       -1.3934  -0.6496  0.0941         (----*----)
                                  ------+---------+---------+---------+---
                                     -1.5       0.0       1.5       3.0


Season = 2 subtracted from:

Season    Lower   Center    Upper  ------+---------+---------+---------+---
3       -1.2760  -0.5420   0.1919         (----*----)
4       -2.4222  -1.6016  -0.7809  (----*-----)
                                   ------+---------+---------+---------+---
                                      -1.5       0.0       1.5       3.0


Season = 3 subtracted from:

Season    Lower   Center    Upper  ------+---------+---------+---------+---
4       -1.7935  -1.0595  -0.3255      (----*----)
                                   ------+---------+---------+---------+---
                                      -1.5       0.0       1.5       3.0
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 2 day rainfall (mussels from Site 1- Muckairn mussels)

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = 0.215
P-Value = 0.156
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 2 day rainfall (Pacific oysters from Camus Driseach)

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = 0.128
P-Value = 0.343
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 2 day rainfall (native oysters from Camus Driseach)

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = -0.044
P-Value = 0.771
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 7 day rainfall (mussels from Site 1- Muckairn mussels)

```
Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.305
P-Value = 0.041
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 7 day rainfall (Pacific oysters from Camus Driseach)

```
Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.043
P-Value = 0.750
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 7 day rainfall (native oysters from Camus Driseach)

```
Pearson correlation of ranked 7 day rain and ranked e coli for rain = -0.006
P-Value = 0.968
```

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the spring/neap cycle (mussels from Site 1- Muckairn mussels)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 23 November 2009 15:58:35

Variables (& observations)	r	p
Angles & Linear (40)	0.343	0.013

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the spring/neap cycle (Pacific oysters from Camus Driseach)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 23 November 2009 16:02:04

Variables (& observations)	r	p
Angles & Linear (75)	0.165	0.141

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the spring/neap cycle (native oysters from Camus Driseach)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 23 November 2009 16:00:07

Variables (& observations)	r	p
Angles & Linear (47)	0.187	0.214

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the high/low cycle (mussels from Site 1- Muckairn mussels)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 23 November 2009 15:57:57

Variables (& observations)	r	p
Angles & Linear (40)	0.219	0.169

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the high/low cycle (Pacific oysters from Camus Driseach)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 23 November 2009 16:02:44

Variables (& observations)	r	p
Angles & Linear (75)	0.105	0.45

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the high/low cycle (native oysters from Camus Driseach)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 23 November 2009 16:01:05

Variables (& observations)	r	p
Angles & Linear (47)	0.147	0.387

Section 11.6.3 Regression analysis – *E. coli* result vs water temperature (mussels from Site 1- Muckairn mussels)

```
The regression equation is
log e coli for temperature = 1.46 + 0.0366 temperature


Predictor       Coef  SE Coef     T      P
Constant      1.4615   0.6742  2.17  0.042
temperature  0.03656  0.06338  0.58  0.571


S = 0.682565   R-Sq = 1.6%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF      SS      MS     F      P
Regression       1  0.1550  0.1550  0.33  0.571
Residual Error  20  9.3179  0.4659
Total           21  9.4729


Unusual Observations

                   log e coli
```

```
                         for
Obs  temperature  temperature    Fit  SE Fit  Residual  St Resid
  8         13.0        3.732  1.937   0.221     1.796      2.78R

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

Section 11.6.3 Regression analysis – *E. coli* result vs water temperature (Pacific oysters from Camus Driseach)

```
The regression equation is
log e coli for temperature = 0.424 + 0.186 temperature


Predictor       Coef  SE Coef     T      P
Constant      0.4238   0.7071  0.60  0.559
temperature  0.18601  0.06594  2.82  0.014


S = 0.858387   R-Sq = 36.2%   R-Sq(adj) = 31.7%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   5.8641  5.8641  7.96  0.014
Residual Error  14  10.3156  0.7368
Total           15  16.1797


Unusual Observations

                   log e coli
                         for
Obs  temperature  temperature    Fit  SE Fit  Residual  St Resid
  6         12.0        1.000  2.656   0.245    -1.656     -2.01R
 15         18.0        3.146  3.772   0.556    -0.626     -0.96 X

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

Section 11.6.3 Regression analysis – *E. coli* result vs water temperature (native oysters from Camus Driseach)

```
The regression equation is
log e coli for temperature = 1.56 + 0.019 temperature


Predictor      Coef  SE Coef     T      P
Constant      1.561    1.478  1.06  0.351
temperature  0.0195   0.1441  0.14  0.899


S = 0.814898   R-Sq = 0.5%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF      SS      MS     F      P
Regression       1  0.0121  0.0121  0.02  0.899
Residual Error   4  2.6562  0.6641
Total            5  2.6684
```

Section 11.6.5 Regression analysis – *E. coli* result vs salinity (mussels from Site 1- Muckairn mussels)

```
The regression equation is
log e coli for salinity = 3.10 - 0.0477 salinity


Predictor      Coef  SE Coef      T      P
Constant     3.0964   0.3618   8.56  0.000
salinity   -0.04765  0.01302  -3.66  0.001


S = 0.674958   R-Sq = 20.5%   R-Sq(adj) = 19.0%


Analysis of Variance

Source          DF       SS      MS      F      P
Regression       1   6.1070  6.1070  13.41  0.001
Residual Error  52  23.6895  0.4556
Total           53  29.7966


Unusual Observations

                 log e coli
Obs  salinity  for salinity     Fit  SE Fit  Residual  St Resid
 15       6.0        2.2041  2.8105  0.2870   -0.6064     -0.99 X
 24      14.0        4.5563  2.4292  0.1913    2.1271      3.29R
 27       4.0        3.7324  2.9058  0.3117    0.8266      1.38 X
 29       0.0        2.1139  3.0964  0.3618   -0.9824     -1.72 X
 36      28.0        3.7324  1.7621  0.0930    1.9703      2.95R

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

Section 11.6.5 Regression analysis – *E. coli* result vs salinity (Pacific oysters from Camus Driseach)

```
The regression equation is
log e coli for salinity = 2.79 - 0.0304 salinity


Predictor      Coef  SE Coef      T      P
Constant     2.7881   0.2235  12.47  0.000
salinity   -0.03044  0.01075  -2.83  0.006


S = 0.884649   R-Sq = 12.0%   R-Sq(adj) = 10.5%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   6.2792  6.2792  8.02  0.006
Residual Error  59  46.1737  0.7826
Total           60  52.4529
```

Hydrographic Methods

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

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

<u>Background processes</u>

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

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

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

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

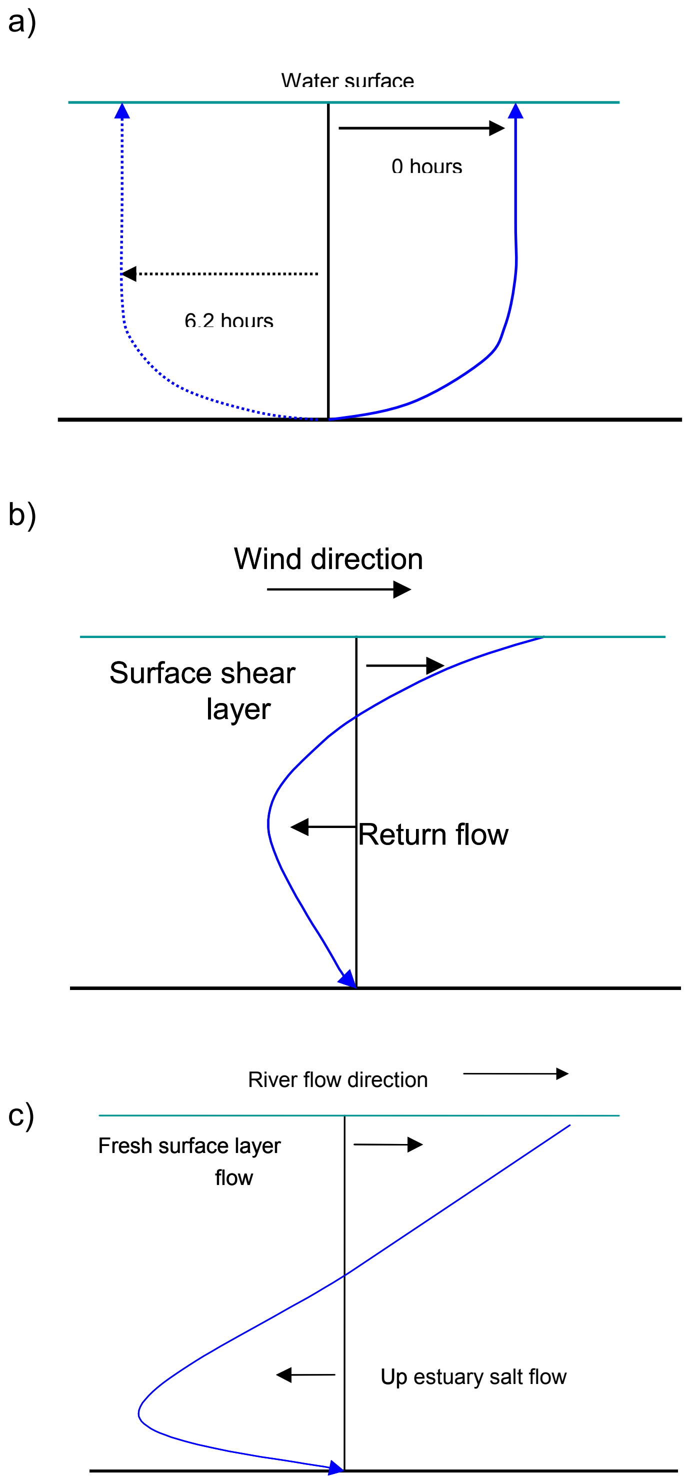

Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

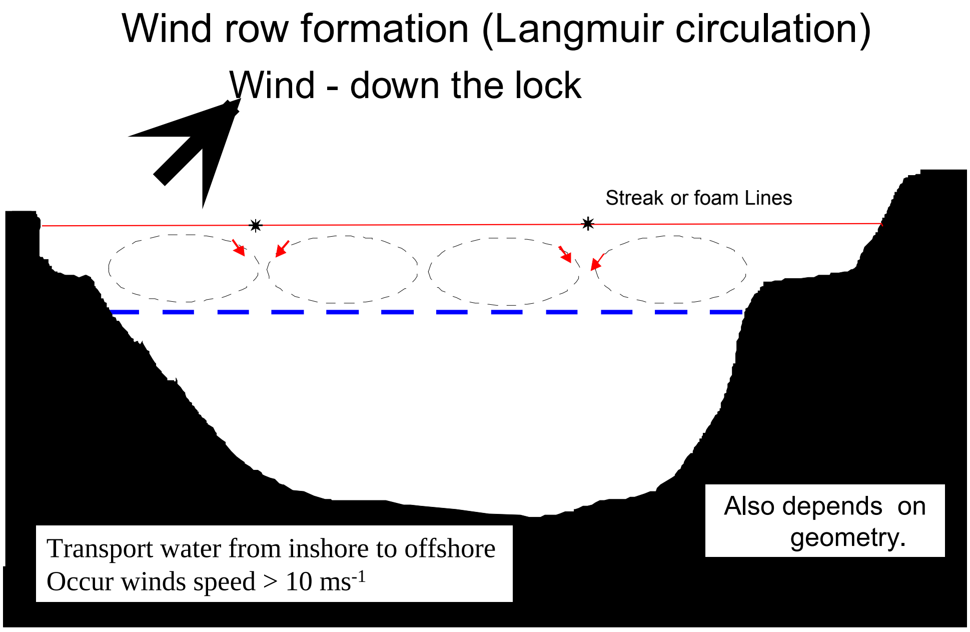

Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

<u>Non-modelling Assessment</u>

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

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

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

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

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

References

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

Glossary

The following technical terms may appear in the hydrographic assessment.

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

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

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

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

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

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

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

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

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

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

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

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

Shoreline Survey Report

Loch Ailort (HL 114)

Scottish Sanitary Survey Project

Shoreline Survey Report

Survey Sites:

Production Area	Site	SIN	Species	Harvester
Loch Ailort	Camus Driseach	HL 114 207 13	Pacific oyster (*Crassostrea gigas*)	Hugh McLaren
	Site 1 Muckairn mussels	HL 114 214 08	Common mussels (*Mytilus* spp)	Alistair Smith
	Eilean Dubh	HL 114 937 08	Common mussels (*Mytilus* spp)	Ian Mackinnon
	Eilean Buidhe	HL 114 209 08	Common mussels (*Mytilus* spp)	Alistair Smith

Local Authority: The Highland Council (Lochaber)
Status: New and existing sites
Date Surveyed: 3-5 November 2009
Surveyed by: Stephen Lewis, Alastair Cook
Existing RMPs: NM 750 822 (mussels) & NM 763 816 (Pacific oysters)
Area Surveyed: See Map in Figure 1

Weather observations

3rd November – Persistent heavy rain, Light westerly winds, air temperature 10 ºC.
4th November – Dry, Light southerly/south easterly winds, air temperature 9 ºC
5th November – Dry, calm, air temperature 7 ºC

Heavy persistent rain had fallen for at least three days before the survey, and quantities of land runoff entering the loch at the time of survey were exceptionally high.

Site Observations

Specific observations made on site are listed in Table 1 and mapped in Figure 1. The locations of these observations were noted using a hand-held GPS receiver. Accuracy recorded by the unit was to within 7 meters.

Fishery

Camus Driseach (Hugh McLaren). Pacific oysters are cultured on trestles in the intertidal zone at the head of the loch, where they take about 2-5 years to reach harvest. A range of sizes were present, including stock of a market size. Harvesting may occur at any time of the year, and the oysters are sold on to a wholesaler. This area is currently classified for the harvest of wild native oysters, but the harvest and sampling have now stopped and the area will be declassified for this species in 2010.

Site 1 – Muckairn mussels (Alistair Smith, Lochailort Mussels). Common mussels are cultured on three lines each of about 200 m in length from which

8 m droppers are suspended. Mussels take about 3 years to grow to a market size. Harvesting was imminent at this site at the time of survey.

Eilean Dubh (Ian Mackinnon). This site consists of 2 300 m longlines, one with extension of a further 100 m from which 5 m droppers are suspended. Stock of a range of sizes was present, including that approaching harvestable size. Harvesting can occur at any time of the year, with the next harvest scheduled for some time in 2010.

Eilean Buidhe (Alistair Smith, Lochailort Mussels). A single line of floats about 200m in length has been deployed here, and at the time of survey no droppers were attached. This site is under the same ownership as Site 1 – Muckairn mussels.

In addition to these aquaculture sites, wild periwinkles (*Littorina littoria*) are commercially gathered by private individuals for sale to local wholesalers prior to export to France and Spain. The area is not currently classified or monitored for this species.

Sewage/Faecal Sources

Human – population on the shores of Loch Ailort is low. Two wastewater discharge pipes were recorded at the head of the loch near the southern end of the trestles. The end of one was below the low water mark so it was not possible to verify that it was in use, but a water sample taken near its end gave a result of 1600 *E. coli* cfu/100ml, suggesting that it may have been. The other was flowing, but was broken and leaking in several places so it was not possible to estimate flow. A water sample taken from the pipe gave a result of >100000 *E. coli* cfu/100ml confirming that is this discharge contained waste water. The sampling officer advised that this discharge is believed to be of raw sewage. In addition to these another septic discharge was seen at the Marine Harvest building on the south shore, and another two septic tank discharges from individual private houses were observed just to the west of Roshven, again on the south shore. Other properties in the area are likely to be served by septic tanks discharging to soakaway or possibly watercourses.

Little in the way of livestock was observed in the area. A fenced field of about 30 sheep was seen by Inverailort Castle on the 3rd November. These were subsequently observed on the salt grass at the head of the loch on 5/11/09 at 1300, but had been moved back by 1600 on 5/11/09. According to the sampling officer, sheep are placed on the salt grass at the head of the loch to graze on a regular basis. Sheep droppings were observed here during the survey. Sheep grazing on this salt grass have direct access to the foreshore on which the trestles are located.

Four horses and a handful of chickens were seen at Roshven, and 9 sheep were seen on the road on the south shore of the outer loch.

Seasonal Population

The area receives significant numbers of visitors mainly during the summer months. There is a hotel at Lochailort and one at Glenuig, and camper vans are reported to be commonly seen in the area during the summer months. Some houses in the area are holiday homes. The bothy at Peanmeanach on the north shore of the outer loch was in use at the time of survey.

A number of caravans were seen along the south shore of the loch, towards its western end. Forsay caravan site hosted about 25 static caravans, a few of which appeared to be in occupation at the time. It is unclear whether these are holiday homes or more permanent accommodation, or a mixture of the two. Also, 5 caravans were seen in a layby close to this site, some of which were occupied.

Boats/Shipping

Boating traffic is limited to a few pleasure craft, and boats associated with the mussel and fish farms. Seven dinghys and small yachts were recorded on moorings just to the east of Roshven. There is an active salmon farm just off the south shore towards the head of the loch, with frequent small boat traffic between its land base on the adjacent shore and the cages. Two yachts and one RIB were seen on moorings in this area.

Land Use

The surrounding land rises steeply to a high altitude in most places. Most of the surrounding land is rough moorland. On the south shore, there are areas of birch woods along the coastal strip. Small areas of pasture were seen in the vicinity of Roshven, and around the head of the loch.

Wildlife/Birds

The area hosts a significant population of red deer, which are frequently sighted by motorists in the region at night. During the course of the survey, two were seen in the gardens of Inverailort Castle, and another two were seen by the bothy at Peanmeanach.

Three adult seals and one pup were seen in the loch, although these were seen at different times and some of these observations may have been repeat sightings of the same animal.

Ten greylag geese were seen grazing on the area of salt grass at the head of the loch, and 8 geese were seen on grassland by Roshven on the south shore. A few seabirds such as cormorants and gulls were seen in various places, but not in great numbers.

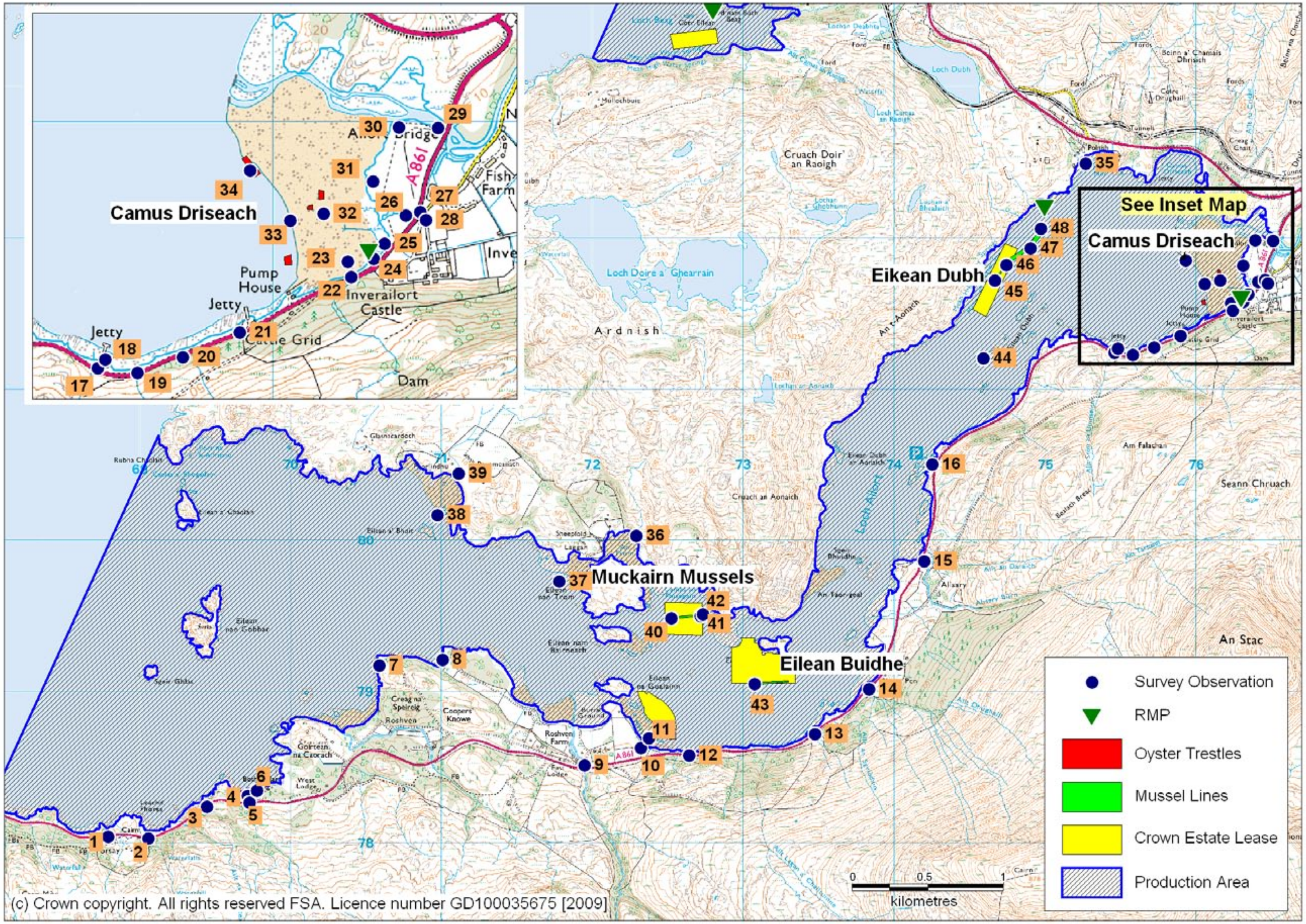

Figure 1. Map of Shoreline Observations

Table 1. Shoreline Observations

No.	Waypt	Date & time	Position	**Easting**	**Northing**	Associated photograph	Observation
1	37	03-NOV-09 1:16:18PM	NM 68789 78041	168789	778041		9 sheep. Forsay Caravan site (about 25 static caravans)
2	38	03-NOV-09 1:31:33PM	NM 69054 78030	169054	778030		Stream 190cmx20cmx2.846m/s. Freshwater sample 14
3	39	03-NOV-09 1:34:13PM	NM 69444 78239	169444	778239		5 caravans
4	67	05-NOV-09 10:14:28AM	NM 69715 78311	169715	778311	Figure 10	Septic tank or possibly package plant with outflow to stream, serves 1 house, not flowing
6	68	05-NOV-09 10:19:32AM	NM 69775 78344	169775	778344	Figure 11	Septic tank with pipe to stream, dripping, serves one house
7	40	03-NOV-09 1:42:06PM	NM 69725 78264	169725	778264		Stream 340cmx40cmx0.493m/s. Water sample 15
7	70	05-NOV-09 11:26:39AM	NM 70589 79172	170589	779172		Seal in bay
8	69	05-NOV-09 11:12:10AM	NM 71005 79208	171005	779208		8 geese
9	12	03-NOV-09 10:44:59AM	NM 71947 78514	171947	778514	Figure 4	River, too large to measure. Water sample 9
10	10	03-NOV-09 10:24:35AM	NM 72319 78626	172319	778626		4 horses and a small chicken shed
11	11	03-NOV-09 10:32:24AM	NM 72373 78692	172373	778692		Seawater sample 8
12	9	03-NOV-09 10:09:39AM	NM 72639 78578	172639	778578		7 small yachts and dinghys on moorings
13	8	03-NOV-09 10:03:30AM	NM 73473 78718	173473	778718		Stream 700cmx35cmx1.193m/s, freshwater sample 7
14	7	03-NOV-09 9:52:13AM	NM 73832 79014	173832	779014		Stream 120cmx50cmx1.753m/s, freshwater sample 6
15	6	03-NOV-09 9:44:37AM	NM 74200 79861	174200	779861		River 800cmx25cmx1.036m/s, freshwater sample 5
16	5	03-NOV-09 9:35:53AM	NM 74252 80501	174252	780501		Seawater sample 4
17	4	03-NOV-09 9:24:33AM	NM 75460 81240	175460	781240		Stream 80cmx20cmx3.2m/s, freshwater sample 3, salmon farm just offshore
18	71	05-NOV-09 12:15:15PM	NM 75483 81267	175483	781267		Marine harvest building. 11 cm orange sewer pipe to shore, dripping

No.	Waypt	Date & time	Position	**Easting**	**Northing**	Associated photograph	Observation
19	3	03-NOV-09 9:17:07AM	NM 75583 81226	175583	781226		Stream 52cmx20cmx0.615m/s, freshwater sample 2
20	2	03-NOV-09 9:09:38AM	NM 75723 81274	175723	781274		Stream 42cmx27cmx0.496m/s, freshwater sample 1
21	1	03-NOV-09 8:59:15AM	NM 75899 81349	175899	781349		Moorings, 2 yachts, 1 RIB
22	63	04-NOV-09 2:00:54PM	NM 76245 81520	176245	781520		Stream 50cmx4cmx2.925m/s. Freshwater sample 26
23	66	04-NOV-09 2:14:19PM	NM 76234 81569	176234	781569	Figure 9	12 cm cast iron pipe, points back towards the large house which hosts Lochailort Post Office, broken in places, clean looking water coming from the breaks, impossible to estimate flow, freshwater sample 27, also 2 net bags of mussels by the end of this pipe
24	64	04-NOV-09 2:03:04PM	NM 76313 81577	176313	781577		Stream 20cmx3cmx1.463m/s. Freshwater sample 25
25	65	04-NOV-09 2:03:52PM	NM 76348 81624	176348	781624		Stream 320cmx12cmx0.170m/s. Freshwater sample 24
26	35	03-NOV-09 12:32:30PM	NM 76413 81710	176413	781710		Stream 80cmx10cmx0.503m/s. Freshwater sample 13
27	36	03-NOV-09 12:35:58PM	NM 76457 81721	176457	781721		Possible hatchery intake
28	13	03-NOV-09 11:13:18AM	NM 76476 81696	176476	781696	Figure 5	2 deer, about 30 sheep in field on other side of road from shore. These were observed on the intertidal grass at the head of the loch on 5/11/09 at 1300, but had been moved back by 1600 on 5/11/09
29	15	03-NOV-09 11:28:56AM	NM 76513 81981	176513	781981	Figure 6	River Ailort, too large to measure. More than 50 cm deep and flowing very quickly. Freshwater sample 10
30	16	03-NOV-09 11:35:47AM	NM 76392 81983	176392	781983	Figure 7	Sheep droppings in tideline
31	14	03-NOV-09 11:21:10AM	NM 76312 81815	176312	781815		10 greylag geese
32	22	03-NOV-09 12:13:55PM	NM 76159 81716	176159	781716		Oyster sample 2
33	34	03-NOV-09 12:23:57PM	NM 76056 81695	176056	781695	Figure 8	10 cm diameter cast iron pipe to underawater. Seawater sample 12 taken near the end of this pipe
34	21	03-NOV-09 12:02:14PM	NM 75932 81849	175932	781849		Seawater sample 11. Oyster sample 1
35	55	04-NOV-09 12:25:43PM	NM 75271 82488	175271	782488		Stream 330cmx21cmx0.369m/s. Freshwater sample 23 House u/s but not possible to enter garden and check for pipe to stream

No.	Waypt	Date & time	Position	**Easting**	**Northing**	Associated photograph	Observation
36	46	04-NOV-09 9:59:43AM	NM 72290 80029	172290	780029		Stream 140cmx10cmx0.670m/s. Freshwater sample 19
37	47	04-NOV-09 10:14:57AM	NM 71779 79728	171779	779728		Holiday house, no pipe visible
38	49	04-NOV-09 10:53:56AM	NM 70971 80164	170971	780164		Seal
39	48	04-NOV-09 10:43:45AM	NM 71113 80441	171113	780441		2 deer. Stream 420cmx33cmx1.106m/s. Freshwater sample 20
40	43	04-NOV-09 9:08:10AM	NM 72523 79483	172523	779483		Inner corner, 3 lines with 8m droppers, seawater sample 17, mussel sample 3 (top) and mussel sample 4 (bottom). Salinity profile 2
41	44	04-NOV-09 9:30:10AM	NM 72717 79499	172717	779499		Seal. Other end of lines. Seawater sample 18
42	45	04-NOV-09 9:32:53AM	NM 72732 79509	172732	779509		Corner of lines. Mussel sample 5 (top), mussel sample 6 (bottom)
43	41	04-NOV-09 8:53:49AM	NM 73074 79051	173074	779051		End of new line, no droppers on this one yet. Seawater sample 16. Salinity profile 1
44	56	04-NOV-09 12:40:15PM	NM 74592 81202	174592	781202		Seal pup on rock
45	50	04-NOV-09 11:35:37AM	NM 74669 81716	174669	781716		Corner of lines (5m droppers). Seawater sample 21. Salinity profile 3
46	51	04-NOV-09 11:41:49AM	NM 74745 81821	174745	781821		Mussel sample 7 (top) and 8 (bottom)
47	54	04-NOV-09 12:04:58PM	NM 74904 81929	174904	781929		Mussel sample 9 (top) and 10 (bottom)
48	53	04-NOV-09 11:58:40AM	NM 74971 82058	174971	782058		Corner of lines. Seawater sample 22

Note: Observations related solely to fishery boundaries were removed from the table so that fishery areas could be clearly seen in Figure 1. Photos referenced in the table can be found attached as Figures 4-11.

Sampling

Water and shellfish samples were collected at sites marked on the maps in Figures 2 and 3. After collection, samples were transferred to coolboxes and transported to Glasgow Scientific Services for *E. coli* analysis. Seawater samples were also tested for salinity. Bacteriology results follow in Tables 2 and 3.

Freshwater samples showed generally low levels of contamination, with the exception to this (>100000 *E. coli* cfu / 100 ml) obtained from a suspected sewage discharge.

The two highest seawater sample results were from the head of the loch (1600 and 210 *E. coli* cfu / 100 ml), though at no location tested were the seawater results below 20 *E. coli* cfu / 100 ml.

Pacific oyster samples collected from the trestles at the head of the loch contained 260 and 330 *E. coli* MPN / 100 g. Mussel samples taken from the farm nearest the head of the loch contained between 230 and 3500 *E. coli* MPN / 100g, while those from nearer the mouth of the loch contained between 130 and 790 *E. coli* MPN / 100g.

Table 2. Water Sample Results

Sample no.	Date & time	Position	**Type**	***E.coli* (cfu/100 ml)**	**Salinity (g/L)**
1	03-NOV-09 9:09:38AM	NM 75723 81274	Freshwater	100	-
2	03-NOV-09 9:17:07AM	NM 75583 81226	Freshwater	<100	-
3	03-NOV-09 9:24:33AM	NM 75460 81240	Freshwater	<100	-
4	03-NOV-09 9:35:53AM	NM 74252 80501	Seawater	120	4.5
5	03-NOV-09 9:44:37AM	NM 74200 79861	Freshwater	<100	-
6	03-NOV-09 9:52:13AM	NM 73832 79014	Freshwater	100	-
7	03-NOV-09 10:03:30AM	NM 73473 78718	Freshwater	<100	-
8	03-NOV-09 10:32:24AM	NM 72373 78692	Seawater	80	28.9
9	03-NOV-09 10:44:59AM	NM 71947 78514	Freshwater	<100	-
10	03-NOV-09 11:28:56AM	NM 76513 81981	Freshwater	180	-
11	03-NOV-09 12:02:14PM	NM 75932 81849	Seawater	210	0.8
12	03-NOV-09 12:23:57PM	NM 76056 81695	Seawater	1600	1.9
13	03-NOV-09 12:32:30PM	NM 76413 81710	Freshwater	5200	-
14	03-NOV-09 1:31:33PM	NM 69054 78030	Freshwater	<100	-
15	03-NOV-09 1:42:06PM	NM 69725 78264	Freshwater	100	-
16	04-NOV-09 8:53:49AM	NM 73074 79051	Seawater	39	18.4
17	04-NOV-09 9:08:10AM	NM 72523 79483	Seawater	22	21.6
18	04-NOV-09 9:30:10AM	NM 72717 79499	Seawater	26	24.5
19	04-NOV-09 9:59:43AM	NM 72290 80029	Freshwater	<100	-
20	04-NOV-09 10:43:45AM	NM 71113 80441	Freshwater	<100	-
21	04-NOV-09 11:35:37AM	NM 74669 81716	Seawater	45	4.4
22	04-NOV-09 11:58:40AM	NM 74971 82058	Seawater	47	4.8
23	04-NOV-09 12:25:43PM	NM 75271 82488	Freshwater	<100	-
24	04-NOV-09 2:03:52PM	NM 76348 81624	Freshwater	<100	-
25	04-NOV-09 2:03:04PM	NM 76313 81577	Freshwater	<100	-
26	04-NOV-09 2:00:54PM	NM 76245 81520	Freshwater	<100	-
27	04-NOV-09 2:14:19PM	NM 76234 81569	Freshwater	>100000	-

Salinity profiles were taken in the field using an electronic salinity meter and probe with 20m cable. Profiles were taken to a maximum of 10 meters depth as the droppers for the mussels do not normally exceed this depth. Salinity profiles are presented in Table 4. These showed that both water temperature and salinity increased with depth, with the vast majority of change occurring between 0 and 2.5 m.

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. Exceptionally heavy rain had preceded the survey, and the River Ailort and the Irine Burn at Roshven were too large to safely measure at the time of survey.

Table 3. Shellfish Sample Results

Sample no.	Date & time	Position	Species	Depth (m)	*E. coli* (MPN/100g)
1	03-NOV-09 12:02PM	NM 75932 81849	Pacific oyster	-	260
2	03-NOV-09 12:13PM	NM 76159 81716	Pacific oyster	-	330
3	04-NOV-09 9:08AM	NM 72523 79483	Mussel	0	790
4	04-NOV-09 9:08AM	NM 72523 79483	Mussel	8	130
5	04-NOV-09 9:32AM	NM 72732 79509	Mussel	0	330
6	04-NOV-09 9:32AM	NM 72732 79509	Mussel	8	230
7	04-NOV-09 11:41AM	NM 74745 81821	Mussel	0	3500
8	04-NOV-09 11:41AM	NM 74745 81821	Mussel	5	490
9	04-NOV-09 12:04PM	NM 74904 81929	Mussel	0	490
10	04-NOV-09 12:04PM	NM 74904 81929	Mussel	5	230

Table 4. Salinity profiles

Profile no.	Date & time	Position	Depth (m)	Salinity (ppt)	Temperature (ºC)
1	04-NOV-09 8:53AM	NM 73074 79051 (Eilean Buidhe)	0	17.4	10.2
			2.5	30.3	11.8
			5	30.6	11.9
			7.5	30.9	11.9
			10	31.3	12
2	04-NOV-09 9:08AM	NM 72523 79483 (Site 1 – Muckairn Mussels)	0	20.4	10.1
			2.5	30.0	11.7
			5	30.4	11.8
			7.5	31.0	11.9
			10	31.5	12
3	04-NOV-09 11:35AM	NM 74669 81716 (Eilean Dubh)	0	1.7	9.1
			2.5	28.4	11.7
			5	29.4	12
			7.5	30.1	12.2
			10	31.1	12.5

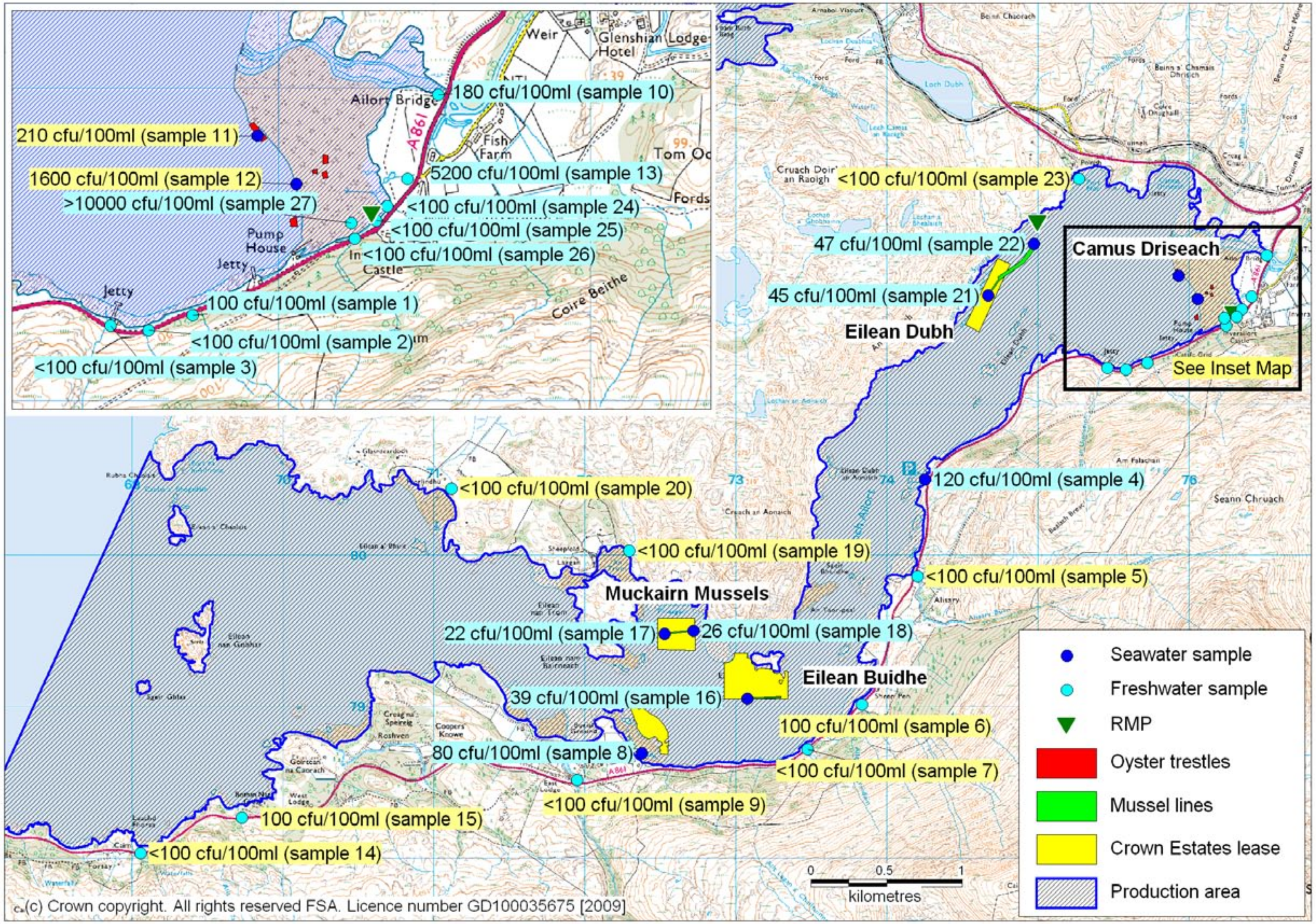

Figure 2. Water sample results map

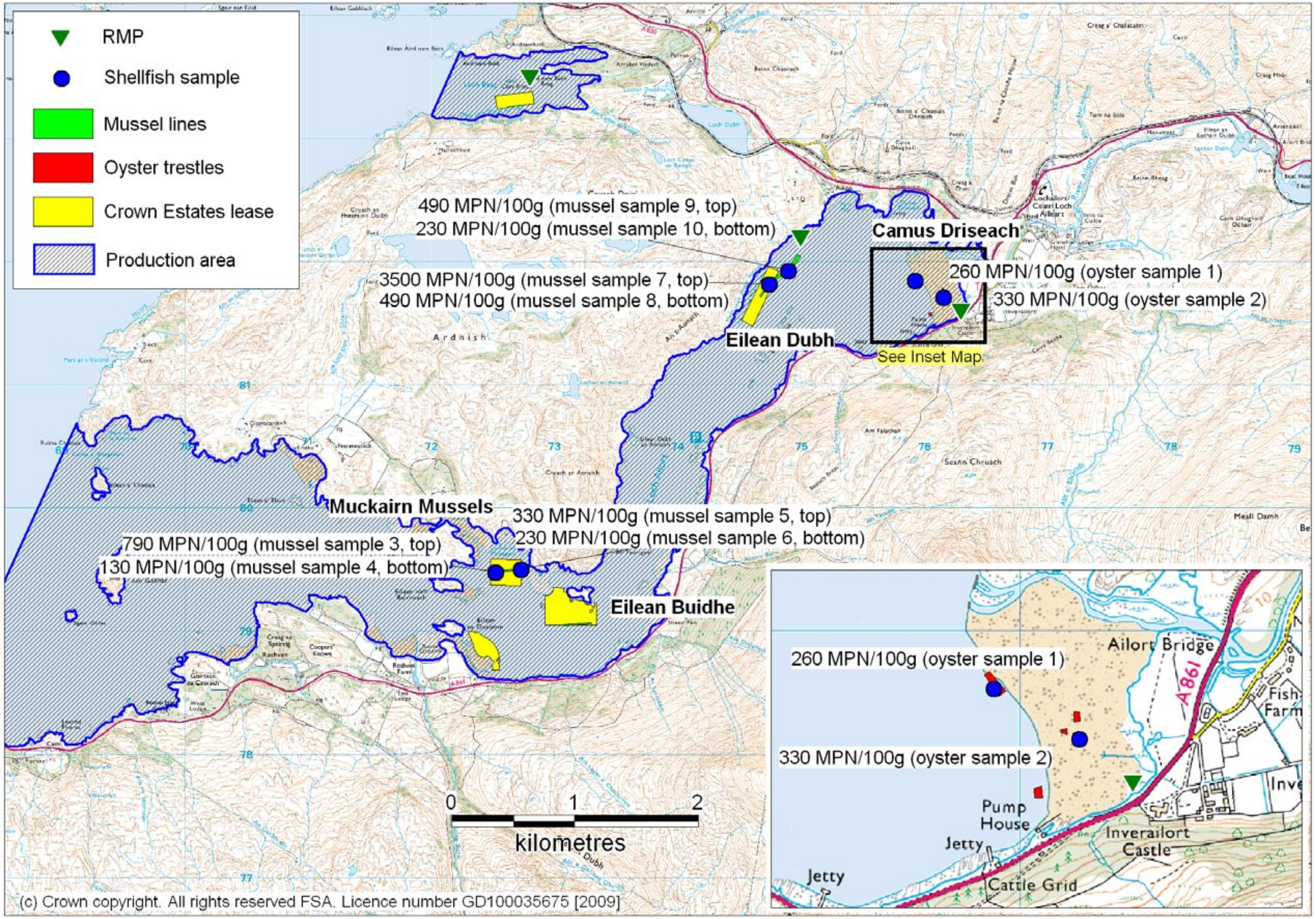

Figure 3. Shellfish sample results map

Figure 4

Figure 5

Figure 6

Figure 7

Figure 8


Figure 9


Figure 10

Figure 11

Norovirus Testing Summary

Loch Ailort (HL 114)

Pacific oyster samples were taken from Loch Ailort on a quarterly basis and submitted for Norovirus analysis.

Results obtained as of the time of writing are tabulated below.

Ref No.	Date	NGR	GI	GII
09/449	11/11/2009	NM 7616 8178	Not detected	Not detected
10/062	01/02/2010	NM 7616 8176	Positive	Not detected
10/226	05/05/2010	NM 7614 8177	Not detected	Not detected
10/359	09/08/2010	NM 7616 8172	Not detected	Not detected