Scottish Sanitary Survey Project

Sanitary Survey Report
Arisaig
HL 004
July 2010

Cefas

Food Standards Agency
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Buidheann Inbhe-Bìdhe

Report Distribution – Arisaig

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

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

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1. General Description

Loch Nan Ceol is a sea loch on the west coast of Scotland, south of Skye. The mouth of the loch splits into north and south channels around a large area of rocky islands and sands. The majority of the loch is enclosed and fairly sheltered. Depths vary from 0 to 10 m, with extensive intertidal areas.

This sanitary survey coincides with the FSA funded norovirus study, which is being undertaken at this site throughout 2009.

Figure 1.1 Location of Arisaig: Loch Nan Ceol

2. Fishery

The area around Arisaig has been classified for the harvest of mussels, carpet clams, surf clams and razor clams for varying periods within the last decade, but none of these fisheries are currently active. In addition, cockles and native oysters were observed on the intertidal sands during the shoreline survey. Currently the area is only classified for Pacific oysters, which are cultured over three sites that are all under the same ownership.

The production area boundaries for Arisaig are lines drawn between NM 6291 8800 to NM 6000 8800 then to NM 6000 8400 and NM 6141 8400 then to NM 6500 8644 and NM 6496 8519 and between NM 6378 8783 and NM 6363 8783. Within the production area, there is one crown estate (CE) lease area, and two representative monitoring points (RMPs) at grid references NM 636 859 and NM 638 853. Active fisheries are listed in Table 2.1

Table 2.1 Active shellfish culture sites at Arisaig

Site	SIN	Species	RMP
Sgeir Philip	HL 004 TBA 13	Pacific oysters	-
Sgeirean Buidhe	HL 004 202 13	Pacific oysters	NM 638 853
Loch nan Ceol	HL 004 198 13	Pacific oysters	NM 636 859

The Sgeir Philip site consists of four discrete areas of wire single trestles and timber stacked trestles with oysters in flat plastic mesh bags or in triangular bags. Most of the stock was small at the time of shoreline survey, with only limited areas holding mature stock. This area is used by the harvester for growing on, with mature stock transferred to the site at Sgeirean Buidhe for hardening off prior to harvest.

The smaller Sgeirean Buidhe site consists of a single area of wire trestles with stock of mature size at the time of shoreline survey.

At Loch nan Ceol, there is a longline site, previously used for mussel culture, that is currently used for the ongrowing of immature Pacific oyster stock which are subsequently moved to the Sgeirean Buidhe site for the final stages of the growth cycle.

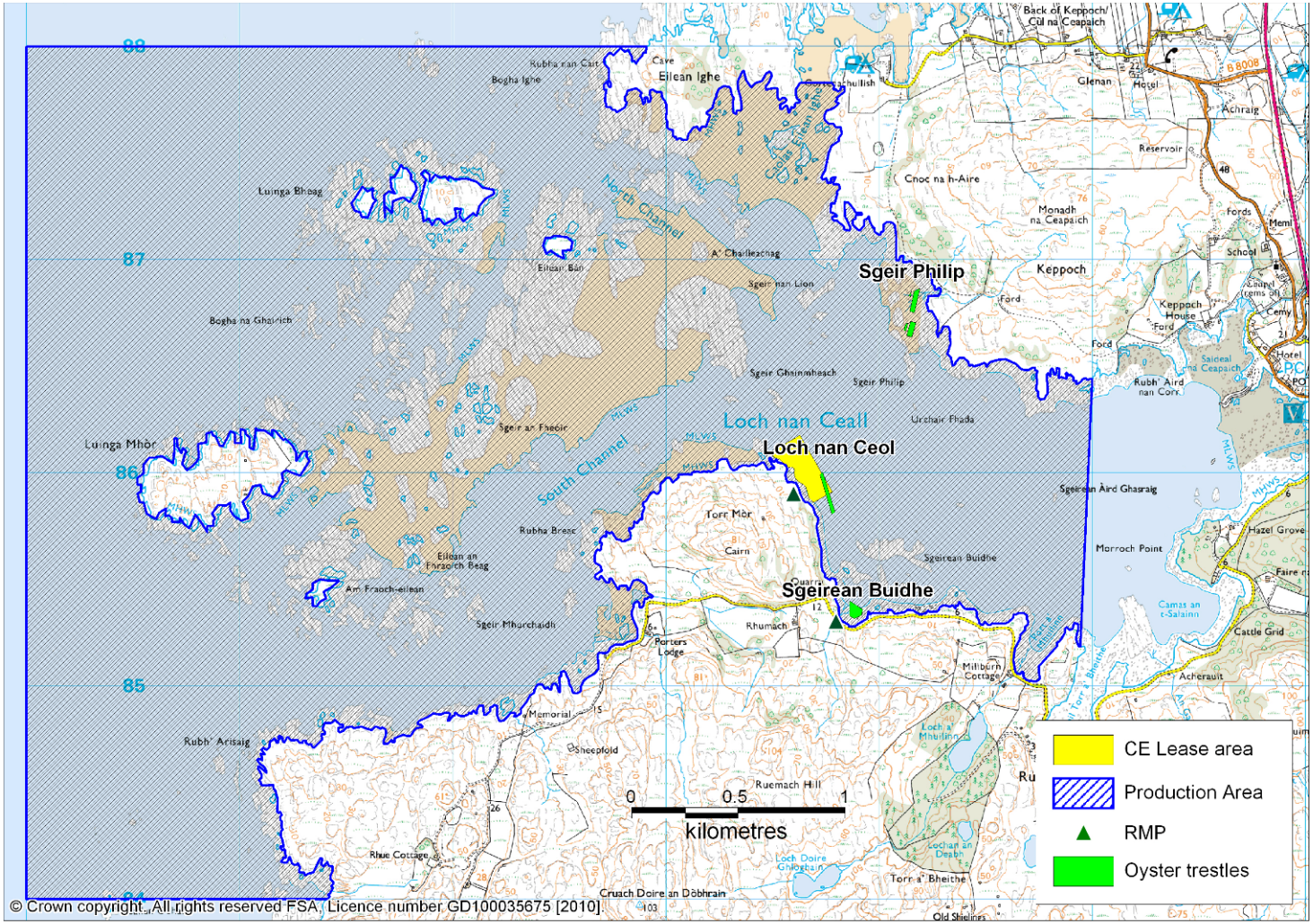

Figure 2.1 Arisaig fishery

3. Human Population

Figure 3.1 shows information obtained from the General Register Office for Scotland on the population within the census output in the vicinity of Arisaig at the time of last census (2001).

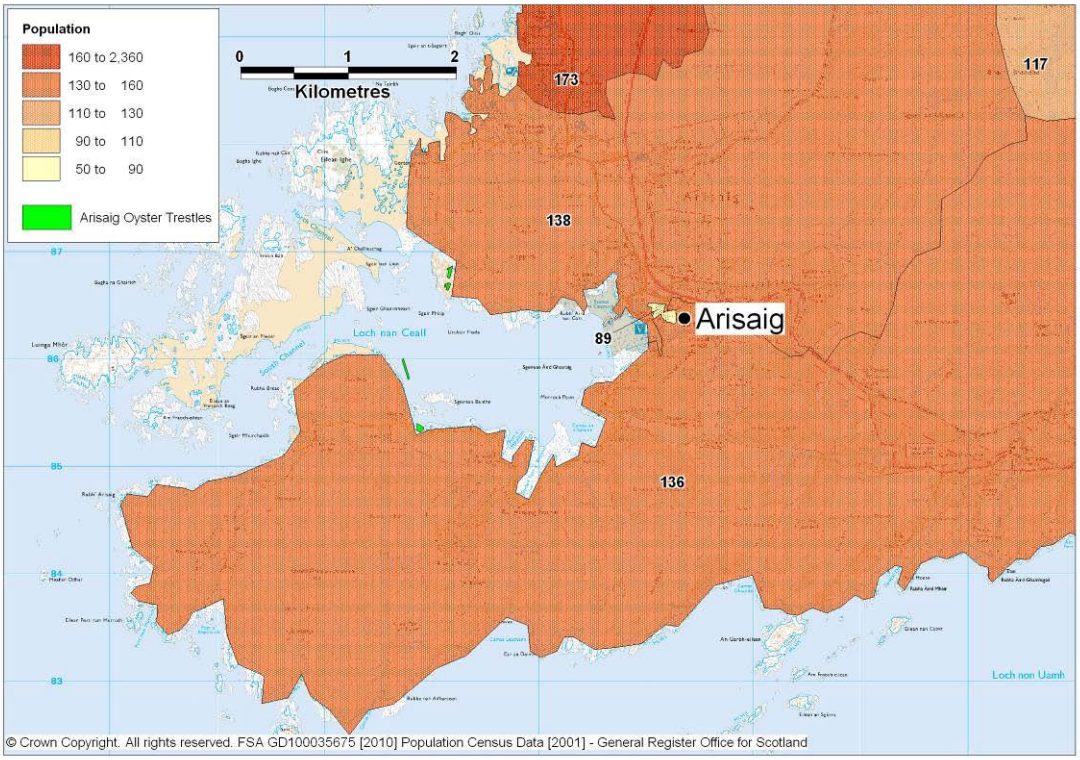

Figure 3.1 Human population in the vicinity of Arisaig

There are two population census output areas immediately bordering Loch Nan Ceall, with populations of 136 to the south, and 138 to the north. The village of Arisaig is close to the loch, and encompasses one census output area with a population of 89. An informal census taken in 1999 listed the population of Arisaig as just over 350 (Hughes, 2000), indicating that nearly all of the population identified for the census output areas described above is concentrated in the vicinity of the village. Therefore, the area is very sparsely populated outside the village. Impacts from human sewage would be expected to low overall and centred around the head of the loch near the village.

Arisaig has tourist accomodation, and attractions such as boat trips to the small isles and a golf course between Arisaig and Morar. The ferry serving the small isles also provides a link for the island populations with the mainland and so is utilised outside the peak tourism months of July and August. Arisaig hosts a traditional Highland Games every summer, though this is not held in the immediate vicinity of the loch. Therefore, it is expected that there will be a significant increase in the human population around the loch during the summer months.

4. Sewage Discharges

One community septic tank was identified by Scottish Water for the area, which is consented to serve 250 people and discharges to the head of the loch at Arisaig (see Table 4.1). There are no overflow discharges associated with this treatment system.

Table 4.1 Scottish Water discharges to Arisaig

Discharge Name	Receiving Water	NGR of discharge	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Population equivalent	Planned improvements?
Arisaig ST	Loch Nan Ceall	NM 6550 8598	Continuous	Septic tank	Not stated	250	No

No sanitary or microbiological data was available for this discharge. Three discharge consents have been issued by SEPA within the area shown in Figure 4.1, details of which are presented in Table 4.2.

Table 4.2 SEPA consents for discharges at Arisaig

Consent no.	Grid ref	Discharges to	Sewage type	Level of treatment	Population equivalent
CAR/R/1017553	NM 6451 8801	Land via soakaway	Domestic	Septic tank	5
CAR/R/1018260	NM 6756 8847	Land via soakaway	Domestic	Septic tank	5
CAR/L/1001637 (Arisaig Septic tank)	NM 6560 8610	Loch Nan Ceall	Treated sewage	Septic tank	250

The first two of these discharges are private domestic septic tanks discharging to soakaway and they are both located over 1 km from the nearest oyster site and so would be expected to have no impact on water quality at the fishery sites. The third of these consents relates to the Arisaig Scottish Water septic tank also listed in Table 4.1

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 Arisaig are presented in Table 4.3.

Table 4.3 Discharge observations made during the shoreline survey

No.	Position	Description
1	NM 66008 86342	Old septic tank
2	NM 66139 86183	New septic tank
3	NM 65763 86594	Septic tank (indeterminate age)
4	NM 65690 85476	13cm diameter clay pipe (flowing).
5	NM 65614 85521	Septic tank with overflow pipe
6	NM 65431 85637	13cm diameter clay pipe (flowing).
7	NM 65437 85647	Stream and pipe both flowing slightly (0.75 ml/s).
8	NM 65571 85763	Discharge pipe. Signs of recent use but not flowing at time of survey
9	NM 65617 85758	Pipe flowing at 0.75 ml/sec.
10	NM 65665 85764	Septic pipe flowing at 15 ml/sec.
11	NM 64660 85055	Clay pipe to stream. No flow
12	NM 65734 86397	Septic tank at boatyard. No pipe apparent at low water.
13	NM 64378 88050	Possible septic tank - wood covered. Near caravan - no pipes apparent

The shoreline survey confirmed the presence of discharges for which consents had not been provided. These were predominantly found along the south shore near Morroch Point, where a number of homes had been built above the shore. Of those pipes found to be actively flowing, three out of the five (observations 6, 7, & 9) were found to contain *E. coli* concentrations ($9.4x10^4$ to $>1.0x10^5$) consistent with septic discharge (Kay et al, 2008). The discharge from the Scottish Water septic tank was not observed. The tank itself was identified at point 2 in Figure 4.1. Observation number 11 related to a home that did not appear to be occupied at the time of survey. A septic tank was identified adjacent to the boatyard at the village jetty, though there were no obvious pipes for either discharge or overflow from this tank. No discharges were observed in the immediate vicinity of the fisheries.

Overall, the risk of poor water quality related to sewage discharges is highest at the head of the loch from the village south and westward. The impact from these on water quality at the oyster farms will depend on dilution and water circulation.

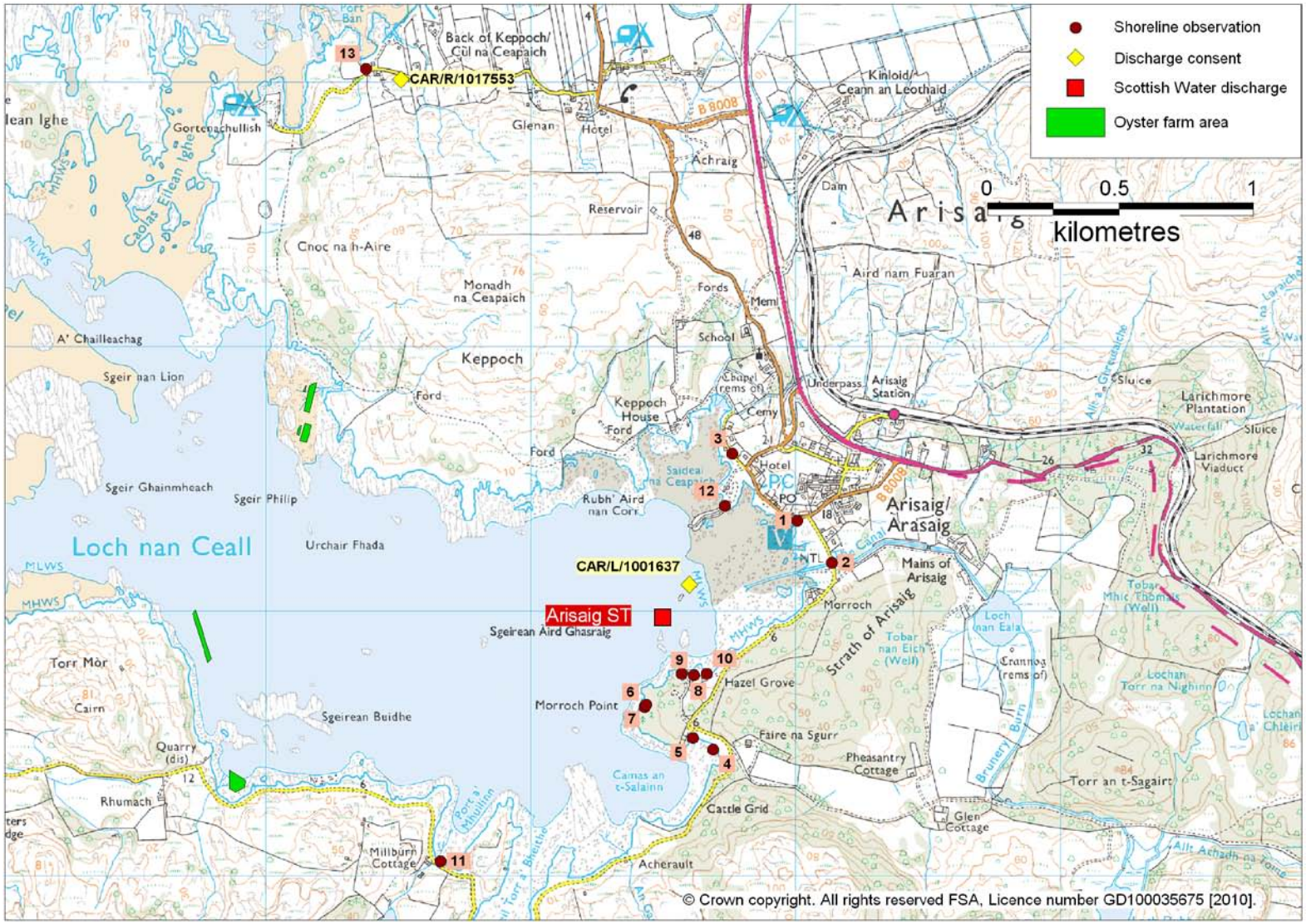

Figure 4.1 Sewage discharges to Arisaig

5. Geology and Soils

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

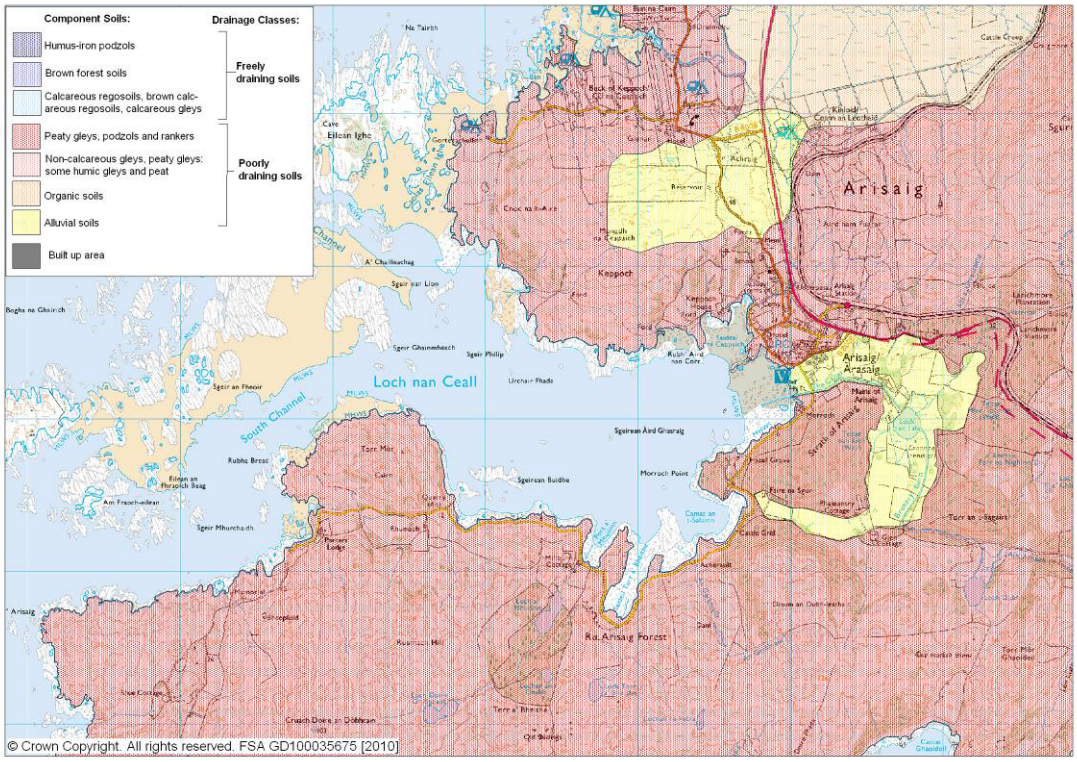

Figure 5.1 Component soils and drainage classes for Arisaig

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 classed as poorly draining.

Overall, the potential for contamination via rainfall runoff that is attributable to soil permeability is high for all the land surrounding Arisaig.

6. Land Cover

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

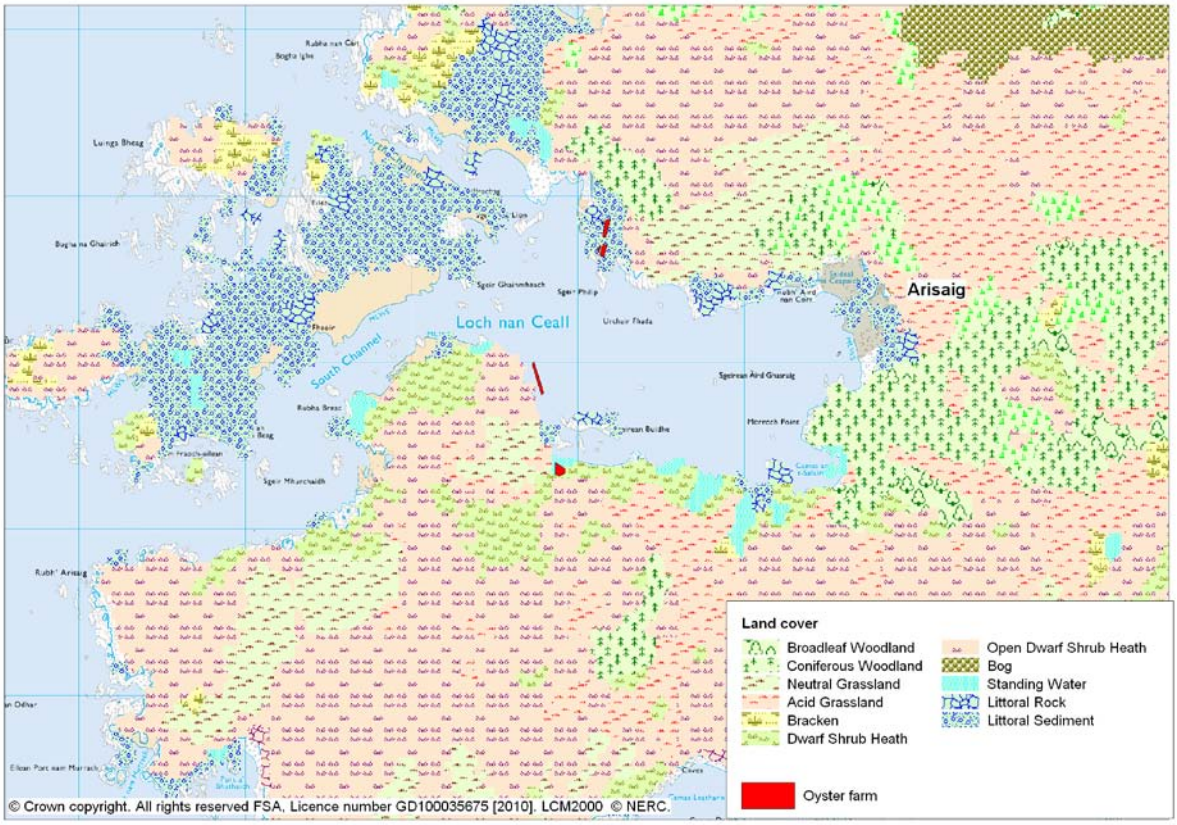

Figure 6.1 LCM2000 class land cover data for Arisaig

The predominant land cover types surrounding Arisaig are open dwarf shrub heath, coniferous woodland, acid grassland and neutral grassland. Small patches of bracken can be found on some of the islands as well as inland and there is an area of bog northeast of the village. The village itself is not noted as built-up area in the LCM2000 data. There are areas of improved grassland north and south of the village, though only the northern area lies near to the shoreline.

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 the improved grassland (approximately 8.3x10^{8} cfu km^{-2} hr^{-1}) and lowest from the 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, this being expected to be highest, at more than 100-fold, for the improved grassland.

The overall predicted contribution of contaminated runoff attributable to land cover type would be low in this area. However, it would be expected to increase significantly following rainfall events. The areas most likely to contribute are the built-up area of the village itself and the improved pasture around it and these would impact primarily at the head of the loch.

7. Farm Animals

Agricultural activities can present a significant risk of faecal contamination to waterways through runoff from grazings, areas of hardstanding, and fields to which slurry has been applied but also from direct deposition to the shoreline and freshwater courses by livestock.

Agricultural census data to parish level was requested from the Rural Environment, Research and Analysis Directorate (RERAD) for the parishes of Arisaig and Moidart. This parish encompasses a land area of 464.3 km^2 that stretches 25 km by 38 km at its widest points. Reported livestock populations for the parishes in 2008 are listed in Table 7.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reporting would have made it possible to discern individual farm data. Any entries which relate to less than five holdings, or where two or fewer holdings account for 85% or more of the information, are replaced with an asterisk.

Table 7.1 Livestock numbers in Arisaig and Moidart Parish 2008

	2008	
	Holdings	Numbers
Pigs	*	*
Poultry	16	4269
Cattle	24	750
Sheep	19	2531
Horses and ponies	8	27

* Data withheld for reasons of confidentiality

Overall, the density of livestock present in the parish is relatively low considering the large area covered. Poultry and sheep are kept in the largest numbers in terms of animals, although a greater number of farms keep cattle.

Due to the large area covered by the parish, this data does not provide information on the livestock numbers immediately surrounding Arisaig and so most likely to influence water quality there. 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 5-10 August 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).

As can be seen from the figure, cattle and sheep were the predominant types of livestock observed, though two ponies were also seen adjacent to a canal on the outskirts of the village. The harvester also noted that he keeps approximately 80 cattle upstream from where the ponies were seen (not mapped). On the north shore of the loch, recently deposited cattle dung was observed along the footpath that leads to the area of oyster trestles near Sgier Philip though no animals were seen directly. The largest concentration of livestock was found southwest of the village, where 34 sheep and 4 cattle were observed. Cattle were also observed to

the north at an area called Back of Keppoch, though these were kept fenced and did not have access to the shore.

Overall, the contribution of livestock to levels of faecal bacteria in the waters is likely to be highest along the southern shore near the head of the loch, based on distributions observed during the shoreline survey. Impact is both through direct deposition onto the shoreline and via runoff from grazed areas. Any contamination from the cattle kept upstream will be carried via the burn leading to the canal and then into the head of the loch.

Figure 7.1 Livestock observed at Loch nan Ceall during shoreline survey

8. Wildlife

General information related to potential risks to water quality by wildlife can be found in Appendix 4. A number of wildlife species present or likely to be present around Loch nan Ceall 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 nan Ceall, small numbers have been recorded on the nearby islands of Rum and Muck, so it is likely that this species also is present in the loch from time to time.

Four adult seals (species uncertain) were recorded during the course of the shoreline survey and an indeterminate number were seen hauled out on rocks immediately offshore of the oyster farm at Sgeirean Buidhe. Seals are therefore present near the fishery and could contribute to levels of faecal contamination found in the loch.

Whales/Dolphins

A variety of whales and dolphins are routinely observed off the west coast of Scotland. Given the shallow entrance to Loch nan Ceall, these animals are unlikely to be present in the vicinity of the fisheries.

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 likely to be a significant population of red deer in the vicinity of Arisaig, no counts were undertaken here at the most recent census (2006). Deer were observed along the road, though none were directly observed during the shoreline survey itself. 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 nan Ceall, but seabirds, wading birds and waterfowl are most likely to occur around or near the fisheries.

Seabirds 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 oyster farms from Seabird 2000 census

Common name	Species	Count	Method	Individual /pair
Great black-backed gull	*Larus marinus*	34	Occupied nests, Occupied territory	Pairs
Herring gull	*Larus argentatus*	105	Occupied nests, Occupied territory	Pairs
European shag	*Phalacrocorax aristotelis*	38	Occupied nests	Pairs
Black Guillemot	*Cepphus grylle*	16	Individuals on land, Individuals on sea	Individuals
Common gull	*Larus canus*	2	Occupied territory	Pairs
Great cormorant	*Phalacrocorax carbo*	23	Occupied nests	Pairs
Arctic tern	*Sterna paradisaea*	1	Occupied territory	Pairs

Only two of these sites occur on Loch nan Ceall. The location of these breeding sites is mapped in Figure 8.1. Where birds have been recorded as pairs, the counts have been doubled. Of the nests or territories listed in Table 8.1, only two sites were within close proximity to the fisheries. Both of these were for gull nests located on rock skerries along the South Channel. Faecal material from the nest site is likely to be either directly deposited or washed into the sea after rainfall. Faeces may also be deposited by adult birds as they fly in search of food. Impact of the latter is assumed to be random and widely distributed.

Waterfowl (ducks, geese, swans) are likely to be present in the area at various times, primarily to overwinter, or briefly during migration. A small number of swans and ducks were observed during the shoreline survey. Their distributions can be found in Figure 8.1. Droppings that were presumed to be from geese may have been from swans. These were observed at locations around the shoreline of the loch, indicating that these birds were present across a wide area. Droppings were particularly numerous south of the village.

Wading birds would be concentrated on intertidal areas, such as the area on which the trestles are located, and small numbers of oystercatchers were seen during the shoreline survey. No further information was found on populations of these birds in the area.

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, would be expected to be very minor.

Summary

In summary, the main wildlife species potentially impacting on the production areas are seals, waterfowl, seabirds and deer. Seals are likely to be present year-round and were observed using skerries near Sgeirean Buidhe to haulout. Impacts from breeding seabirds are unlikely to directly affect either oyster farm due to the distance. Swans and 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. Their faeces were seen on the shoreline on either side of the village, which is consistent with areas of improved pasture identified in Landcover2000 data. Contamination from deer will be carried into the production area by streams draining the surrounding hills and this will occur all year round. The impacts will be highest where streams enter the loch, and this may have a higher impact at the Sgeirean Buidhe site, where a stream runs through the trestle area.

Figure 8.1 Breeding seabirds and wildlife observations at Loch nan Ceall

9. Meteorological data

The nearest weather station is located at Inverailort, 12 km to the south east of the production area, 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 72 km to the south-west of the production area. Local topography may result in some significant differences in overall wind patterns at Loch Ailort and Tiree, and conditions on any given day 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 Arisaig.

9.1 Rainfall

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

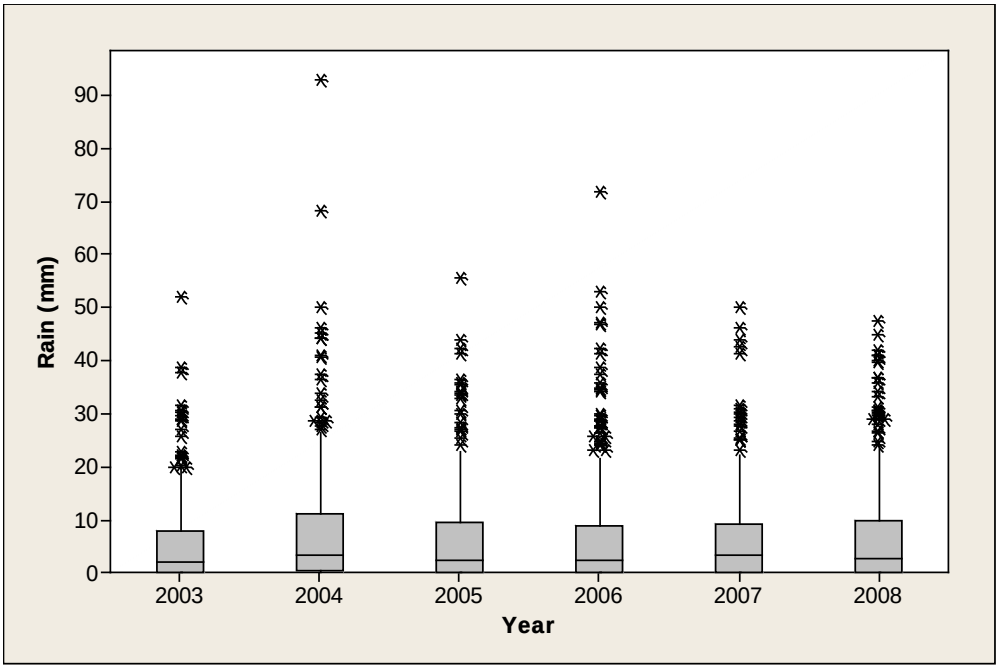

Figure 9.1 Box plot of daily rainfall values by year at Inverailort, 2003-2008

Figure 9.1 shows that rainfall patterns were similar between the years presented here, with 2003 the driest and 2004 the wettest. Extreme rainfall events were highest in 2004 and 2006, but in most years the maximum daily rainfall was between 50 and 60 mm.

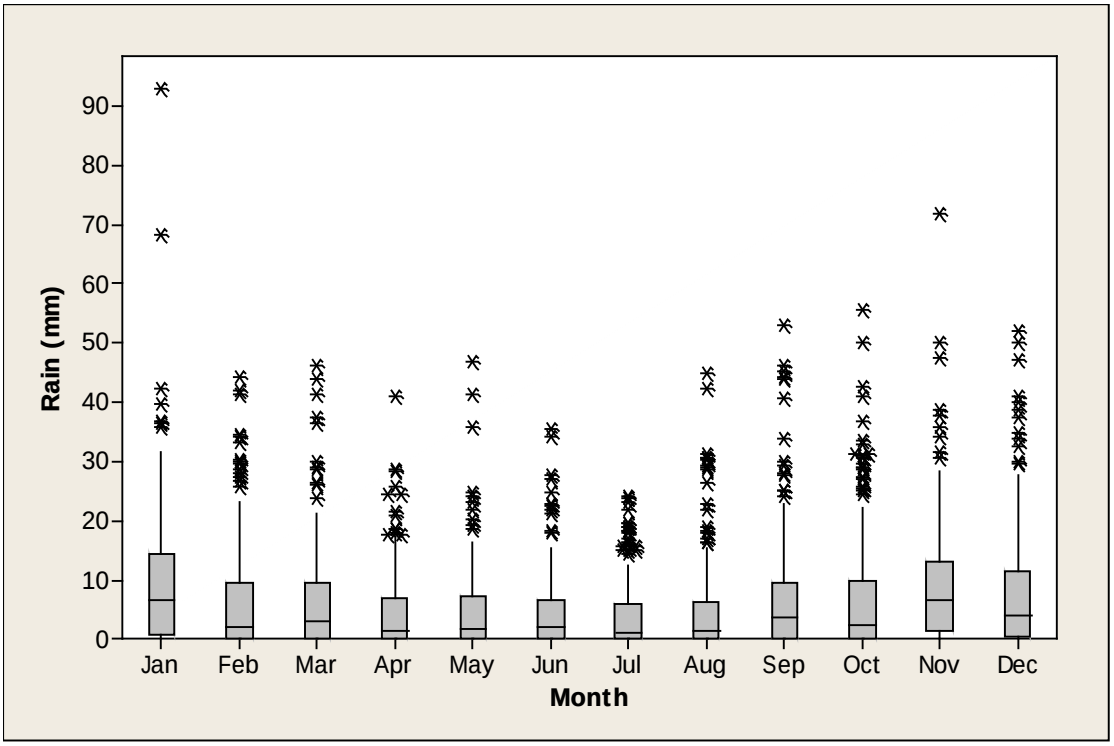

Figure 9.2 Box plot of daily rainfall values by month at Inverailort, 2005-2008

The wettest months were November, December and January, and April to August were the driest months. Days with high rainfall can occur at any time of the year, though days with rainfall >50 mm only occurred from September to January in this dataset. 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.

It can therefore be expected that levels of rainfall dependent-faecal contamination entering the production area from will be higher during the autumn and winter 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.

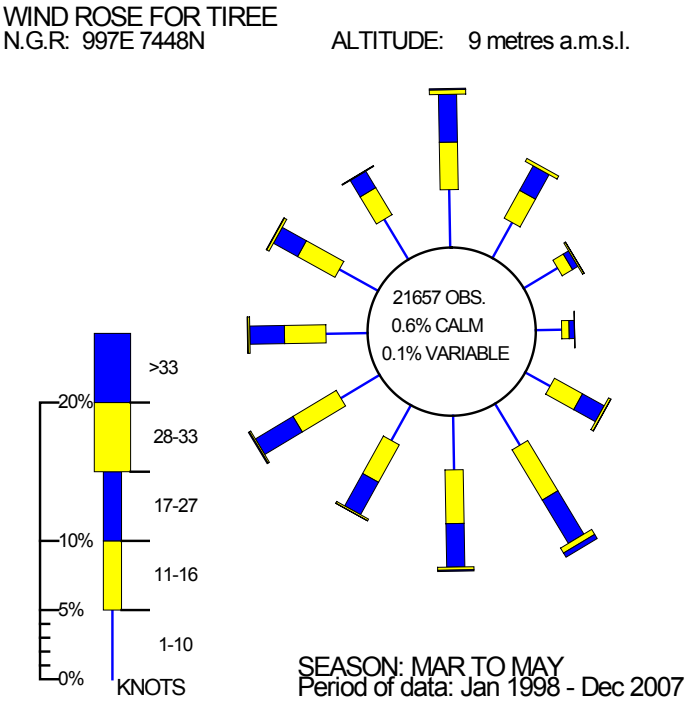

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Figure 9.3 Wind rose for Tiree (March to May)

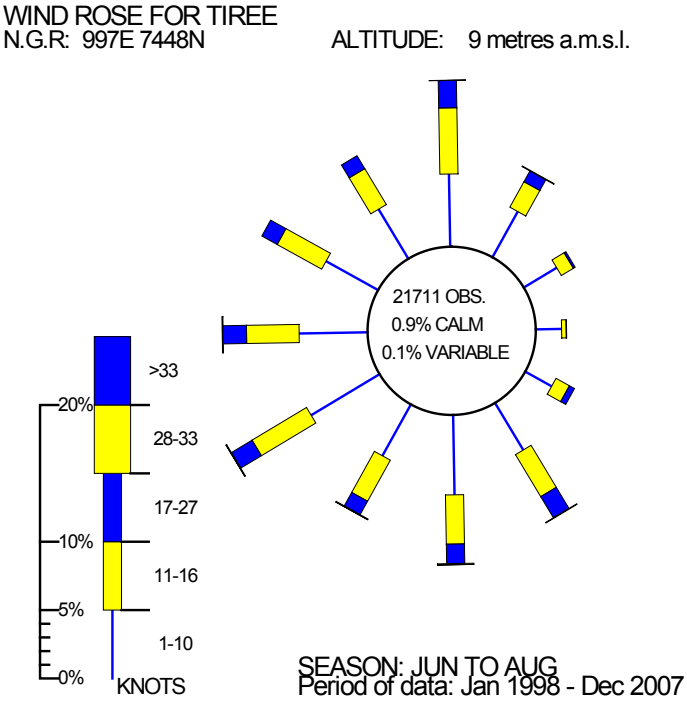

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Figure 9.4 Wind rose for Tiree (June to August)

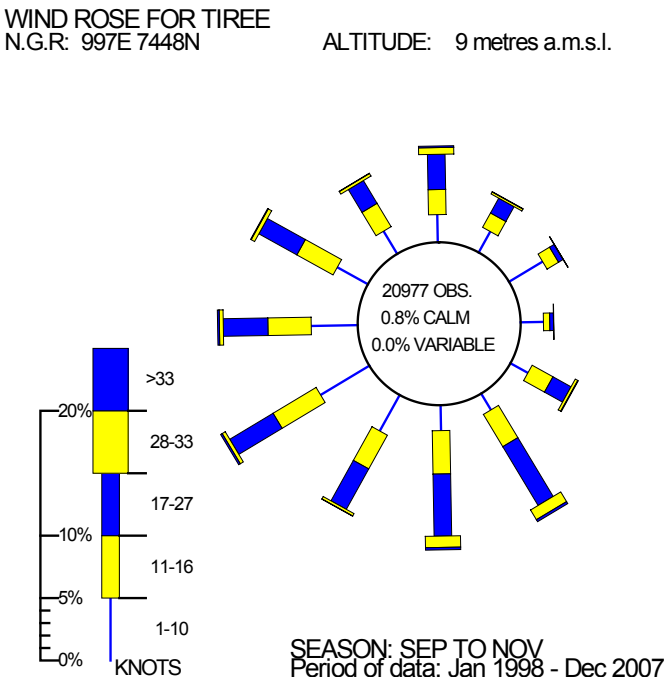


Figure 9.5 Wind rose for Tiree (September to November)

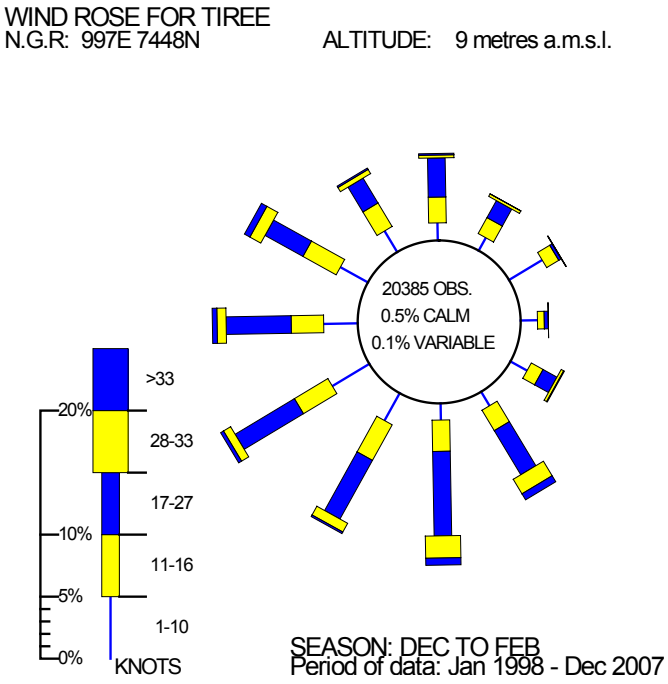


Figure 9.6 Wind rose for Tiree (December to February)

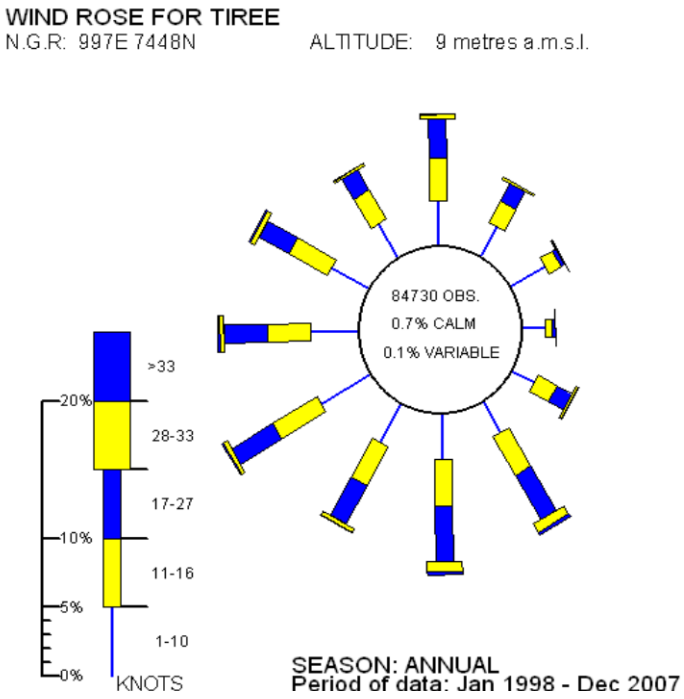


Figure 9.7 Wind rose for Tiree (All year)

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. There is a higher occurrence 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. Winds are generally lightest in the summer and strongest in the winter. Arisaig faces north west, but receives shelter from wind and waves from this direction from rocky islands and shallow sands across the mouth of the loch. It is surrounded by low hills which rise to over 100 m in places. Therefore, overall wind patterns are likely to differ significantly from Tiree, and will be more skewed towards the north and west, and it is also likely that they will be generally lighter than those experienced at Tiree as Arisaig is in a more sheltered location.

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

10. Current and historical classification status

Arisaig has been classified for the production of mussels, Pacific oysters, carpet clams, surf clams and razor clams for varying periods in recent years. It is currently classified for the production of mussels and Pacific oysters. Classification histories for the various species are presented in Tables 10.1 to 10.5. A map of the current production area can be found in Section 2, Figure 2.1.

Table 10.1 Classification history, Arisaig, mussels

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

* Declassified

For mussels, the area has seasonal A/B classifications in 2003 and from 2007 to 2008/9, and A classifications from 2004 to 2006. Aside from in 2003, B months have occurred during the second half of the year.

Table 10.2 Classification history, Arisaig, Pacific oysters

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

For Pacific oysters, the area has held seasonal A/B classifications throughout its classification history, with the timing of B months varying from year to year.

Table 10.3 Classification history, Arisaig, carpet clams

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

* Declassified

For carpet clams, the area has held an A classification throughout its classification history, but is not currently classified for this species.

Table 10.4 Classification history, Arisaig, surf clams

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002	b	b	b	b	b	b	b	b	b	b	b	b

Lower case denotes provisional classification

For surf clams, the area received a provisional B classification for 2002, and has not been classified since.

Table 10.5 Classification history, Arisaig, razor clams

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	a	a	a	a	a	a	a	a	a	a	a	a

Lower case denotes provisional classification

For razor clams, the area received a provisional A classification for 2001, and has not been classified since.

11. Historical E. coli data

11.1 Validation of historical data

All shellfish samples taken from Arisaig 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.

One sample had the wrong prefix (NN) to its grid reference, and this was corrected to NM. One carpet clam sample plotted on land 260 m outside the production area and so was excluded from the analysis. Forty-eight mussel samples and one Pacific oyster sample were reported from NM 636 859 (the mussel RMP), which plotted on land 33 m outside the production area. Twenty-five Pacific oyster samples were reported from NM 638 853 (the Pacific oyster RMP), which plotted on land 24 m outside the production area. As these two grid references were reported to 100 m accuracy, and they were within 100 m of the production areas, samples from these locations were included in the analysis.

No samples were excluded from the analysis on the basis of sampling date discrepancies.

Twenty-two mussel samples, 4 Pacific oyster samples and 19 carpet clam samples had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation.

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

11.2 Summary of microbiological results

A summary of all sampling and results by site and species are presented in Table 11.1. Results for North Channel mussels, South Channel carpet clams, Luiga Bheag carpet clams and Loch nan Ceol Pacific oysters 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.

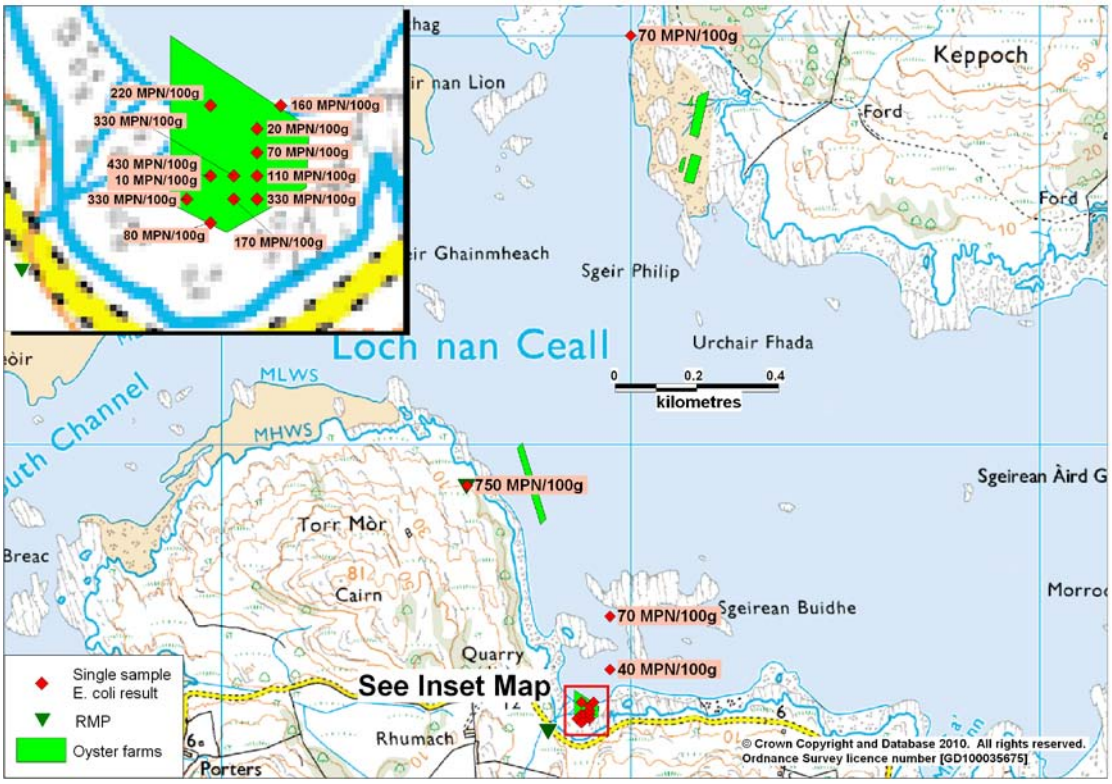
Table 11.1Summary of historical sampling and results

Sampling Summary							
Production area	Arisaig	Arisaig	Arisaig	Arisaig	Arisaig	Arisaig	Arisaig
Site	Loch nan Ceol	North Channel	North Channel	South Channel	Luinga Bheag	Sgeirean Buidhe	Loch nan Ceol
Species	Common mussels	Common mussels	Carpet clams	Carpet clams	Carpet clams	Pacific oysters	Pacific oysters
SIN	HL-004-198-08	HL-004-200-08	HL-004-200-02	HL-004-203-02	HL-004-199-02	HL-004-202-13	HL-004-198-13
Location	2 locations	NM635874	7 locations	2 locations	2 locations	18 locations	NM638853
Total no of samples	58	1	38	5	2	40	1
No. 2002	8	1	11	3	2	0	0
No. 2003	8	0	6	2	0	0	0
No. 2004	10	0	6	0	0	2	0
No. 2005	9	0	6	0	0	9	0
No. 2006	10	0	2	0	0	8	0
No. 2007	6	0	6	0	0	5	1
No. 2008	7	0	1	0	0	7	0
No. 2009	0	0	0	0	0	9	0
Results Summary							
Minimum	<20		<20	<20	<20	<20	
Maximum	1300		16000	70	<20	750	
Median	20	3500	20	20	<20	95	160
Geometric mean	36		27	25		100	
90 percentile	346		76			500	
95 percentile	538		217			750	
No. exceeding 230/100g	9 (16%)		2 (5%)			13 (33%)	
No. exceeding 1000/100g	2 (3%)		1 (3%)			0 (0%)	
No. exceeding 4600/100g	0 (0%)		1 (3%)			0 (0%)	
No. exceeding 18000/100g	0 (0%)		0 (0%)			0 (0%)	

11.3 Overall geographical pattern of results

Figures 11.1 to 11.3 present a maps showing geometric mean result by reported sampling locations for mussels, carpet clams and Pacific oysters.

Pacific oysters



Note: Samples (25) reported against the RMP at Sgeirean Buidhe are not mapped above (see text).

Figure 11.1 Map of sampling points and geometric mean result (Pacific oysters)

One result recorded against the Loch nan Ceol mussel site RMP gave a result of 750 *E. coli* MPN/100 g. Another from the north shore north of the mussel farms at Sgeir Philip gave a result of 70 *E. coli* MPN/100 g. Both were reported as originating from the Sgeirean Buidhe site, so either their sampling locations or site of origin are likely to be inaccurate. Results reported against the Sgeirean Buidhe RMP (25 samples) ranged from <20 to 750 *E. coli* MPN/100 g, with 8 out of 25 results greater than 230 *E. coli* MPN/100 g. However, as these samples may have come from anywhere on the Sgeirean Buidhe site, the results are not represented in Figure 11.1. Aside from the RMP, no other location was sampled on more than 2 occasions so a statistical evaluation of geographic differences in levels of contamination was not possible. Results appeared to be higher for samples taken from near a stream that flows across the foreshore on the west side of the oyster trestles.

Mussels

Figure 11.2 Map of sampling points and geometric mean result (mussels)

All but one of these samples originated from the Loch nan Ceol site. The sample which gave the highest result was the only sample taken from the North Channel site. Two locations were sampled at the Loch nan Ceol site, with results on average lower at the RMP, but this difference was not significant (T-test, T=-2.12, p=0.057, Appendix 6). There was also no significant difference in the proportion of results exceeding 230 *E. coli* MPN/100g between either location sampled at Loch nan Ceol (Fishers Exact test, p=0.619, Appendix 6). These locations were never both sampled on the same occasion. All results greater than 230 MPN/100 g prior to 2008 (7 results) were reported against the nominal RMP and those from 2008 were reported against the other grid reference. Therefore, the variation in results may be due to the way that sampling location was reported over time rather than a true geographic effect.

Carpet clams

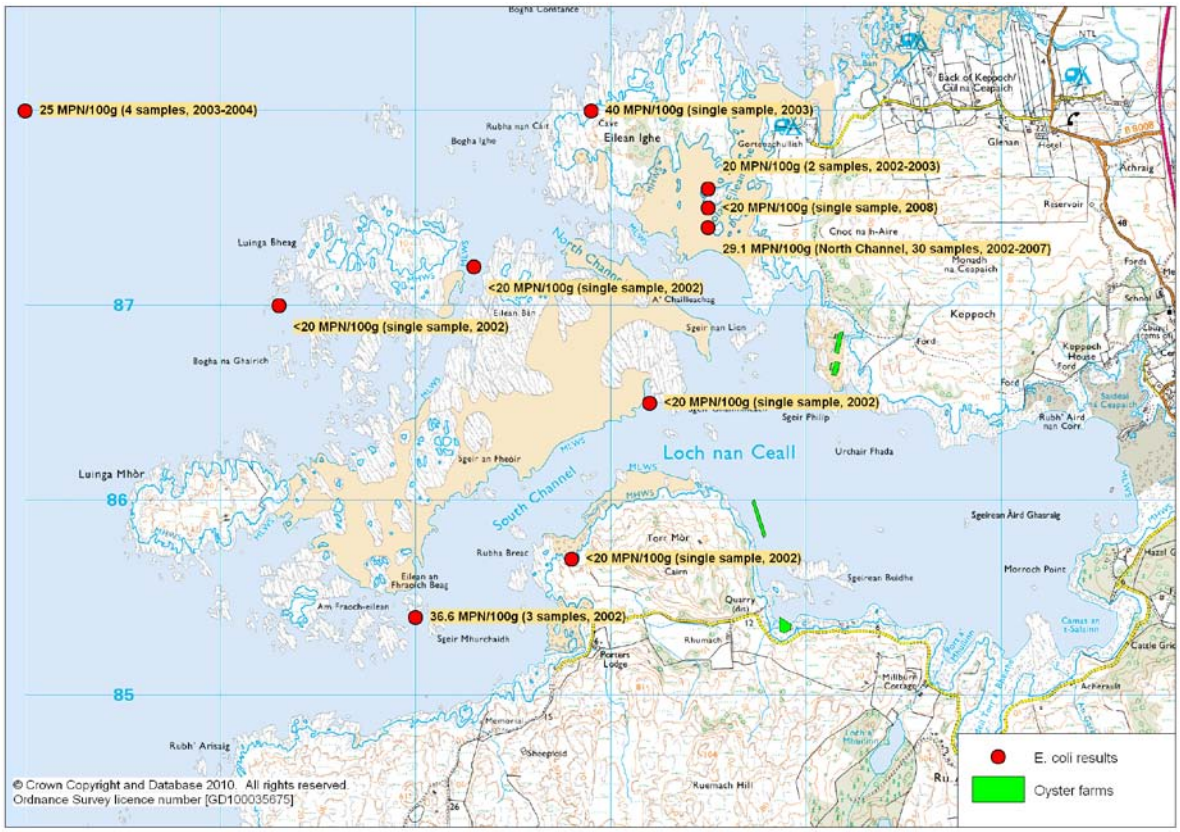


Figure 11.3 Map of sampling points and single and geographic mean results (carpet clams)

Aside from one location which was sampled on 30 occasions, all other sampling locations were only sampled four or fewer times and so a statistical evaluation of geographic differences in levels of contamination was not possible. Figure 11.2 shows that results were consistently low for carpet clams throughout the whole production area. Points have not been thematically mapped due to the mixture of geographic mean and single results. One exception was a sample taken in 2002 at the location that was sampled on 30 occasions which gave a result of 16000 *E. coli* MPN/100g, and this result is masked on Figure 11.2 by the use of the geometric mean result at this point.

11.4 Overall temporal pattern of results

Figures 11.5 to 11.7 present scatter plots of individual results against date for mussels from Loch nan Ceol, carpet clams from North Channel and Pacific oysters from Sgeirean Buidhe. There was insufficient data from the other site/species combinations to present in this manner. The graphs 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 present in the data.

Pacific oysters

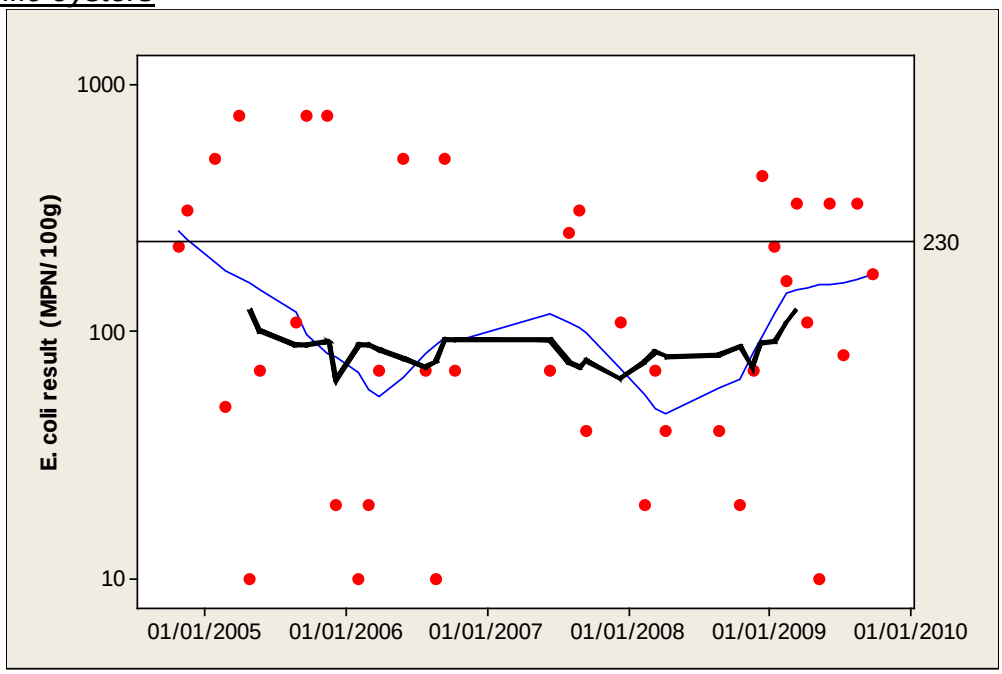


Figure 11.4 Scatterplot of *E. coli* results by date with rolling geometric mean (black line) and loess line (blue line) (Pacific oysters from Sgeirean Buidhe)

Figure 11.6 suggests a cyclical pattern in Pacific oyster results, not coinciding with year, with the Loess line highlighting improvements in results in early 2006 and again in early-mid 2008. All results since September 2006 have been less than 500 *E. coli* MPN/100 g and for a period between August 2007 and November 2008 no results greater than 230 *E. coli* MPN/100 g were obtained. Overall, there appears to be a slight improvement in contamination levels since 2004.

Interestingly, the patterns observed in results for the three different species differed considerably and this may be indicative of different drivers of contamination in each of the fisheries.

Mussels

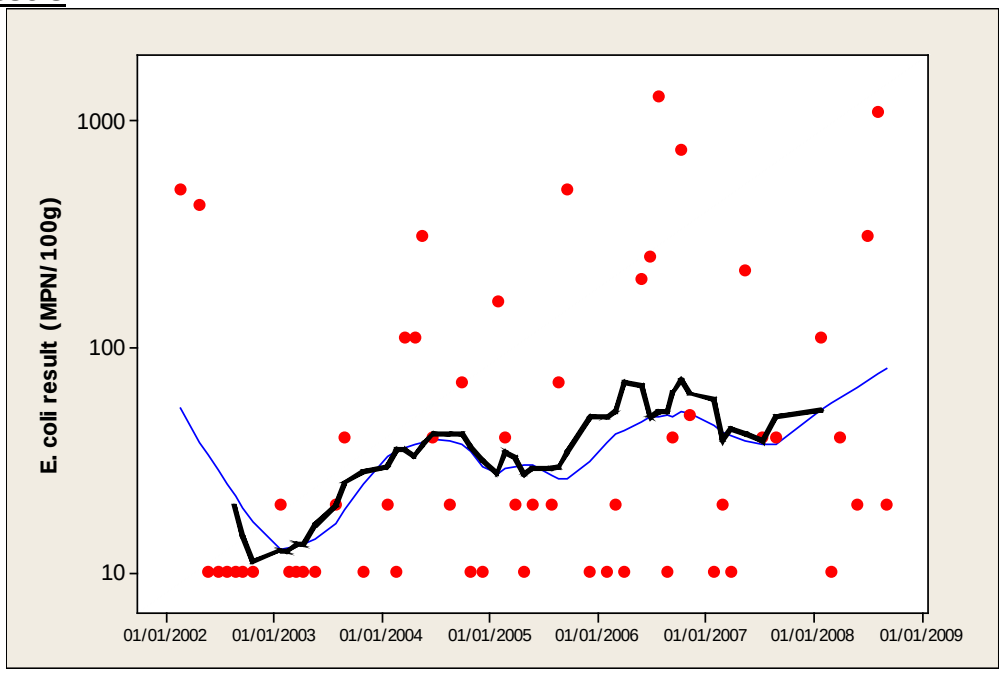


Figure 11.5 Scatterplot of *E. coli* results by date with rolling geometric mean (black line) and loess line (blue line) (mussels from Loch nan Ceol)

Figure 11.5 suggests that results for mussels deteriorated overall, with more high results and fewer low results occurring from 2004 onwards.

Carpet clams

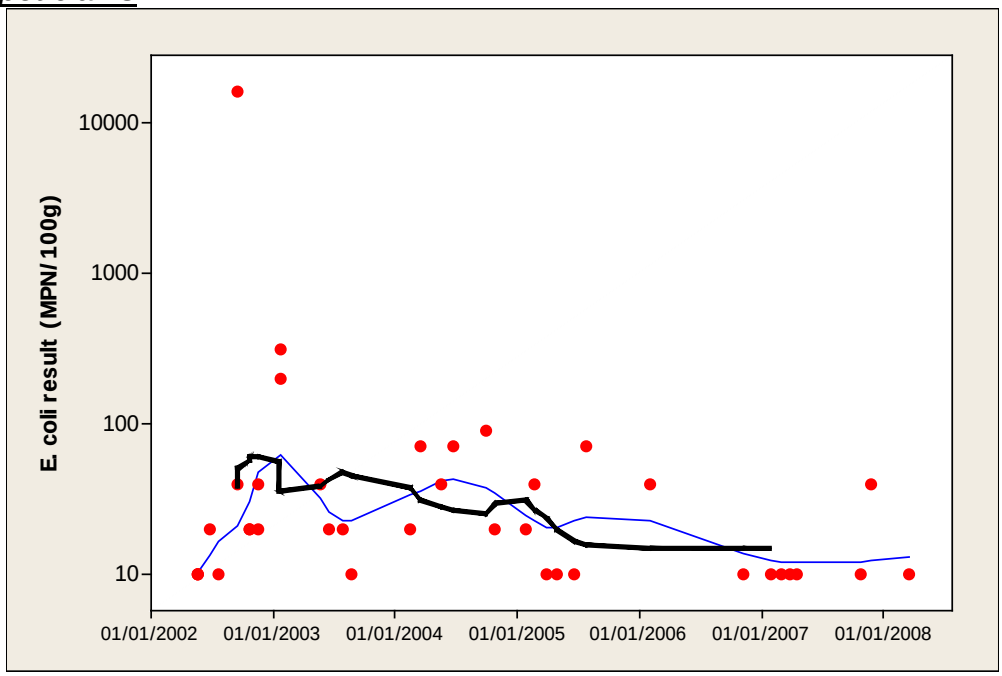


Figure 11.6 Scatterplot of *E. coli* results by date with rolling geometric mean (black line) and loess line (blue line) (carpet clams from North Channel)

Aside from one extremely high result in 2002, results for carpet clams have shown low levels of contamination throughout the sampling history, possibly slightly improving between 2002 and 2009.

11.5 Seasonal pattern of results

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns of human occupation. All of these can affect levels of microbial contamination, and cause seasonal patterns in results. From this point forward, only results for Pacific oysters will be considered, as the area is only classified for this species. Figures 11.8, 11.9 and 11.10 present individual value plots of *E. coli* result by month for mussels from Loch nan Ceol, carpet clams from North Channel and Pacific oysters from Sgeirean Buidhe respectively. Box plots could not be presented due to the low numbers of samples taken in some months.

Variation by Month

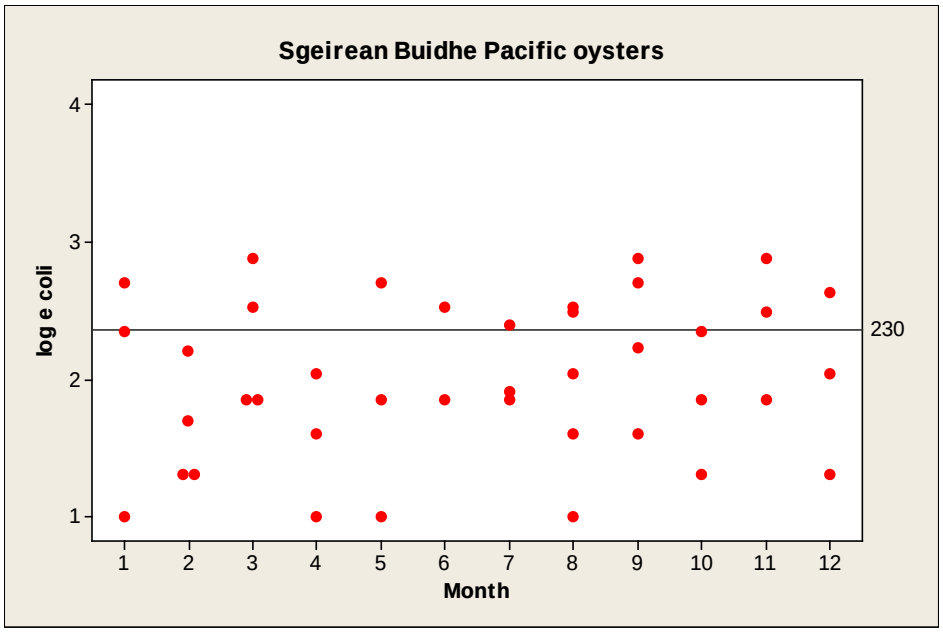


Figure 11.7 Boxplot of results by month (Pacific oysters from Sgeirean Buidhe)

Many months had fewer than 5 samples. Results of 230 *E. coli* MPN/100 g or greater occurred in all months except February and April. No seasonal pattern is apparent in Figure 11.7.

Variation by Season

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

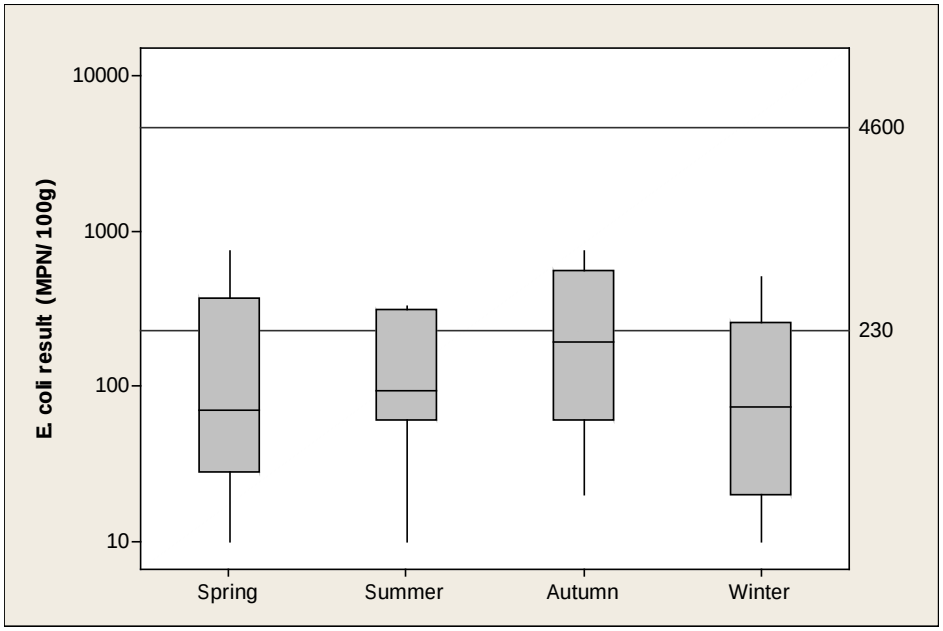


Figure 11.8 Boxplot of result by season (Pacific oysters from Sgeirean Buidhe)

No significant difference was found between results by season for Pacific oysters from Sgeirean Buidhe (One-way ANOVA, p=0.545, Appendix 6). However, there does appear to be a trend in median results, with the highest median result occurring in Autumn.

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, 12 km to the south east of the production area. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2008 (total daily rainfall in mm). Spearman's Rank correlations were carried out between results and rainfall. Figures 11.9 and 11.10 present scatterplots of *E. coli* results against rainfall for Pacific oysters from Sgeirean Buidhe. 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 2 and 7 days and sample results was investigated.

2-day antecedent rainfall

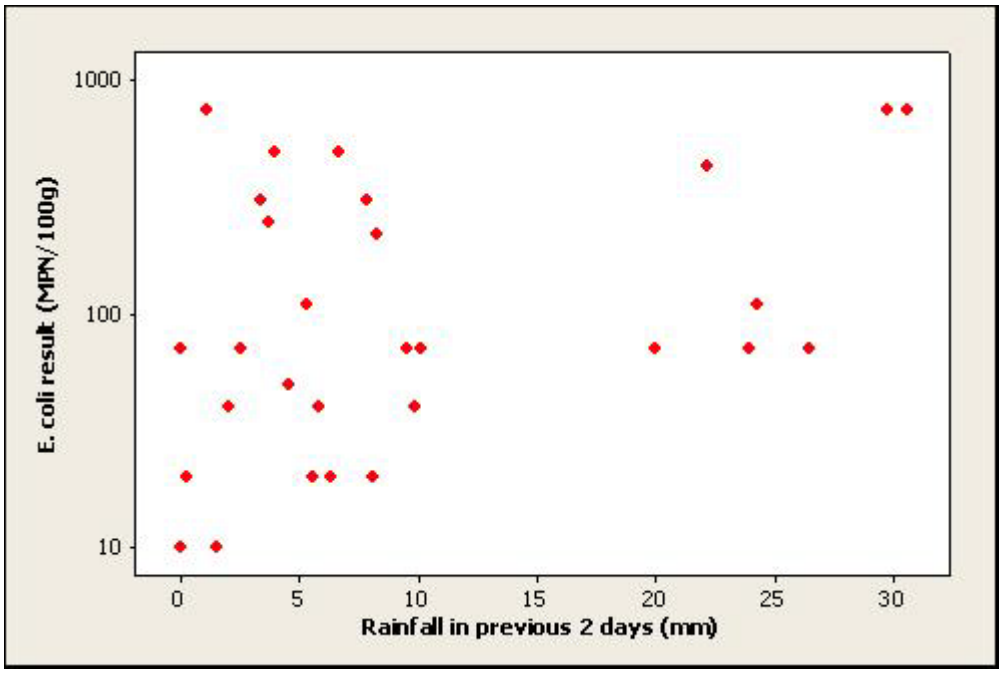


Figure 11.9 Scatterplot of result against rainfall in previous 2 days (Pacific oysters from Sgeirean Buidhe)

A weak positive correlation was found between *E. coli* results for Pacific oysters from Sgeirean Buidhe and rainfall in the previous 2 days (Spearman's rank correlation=-0.400, p=0.029, Appendix 6).

7-day antecedent rainfall

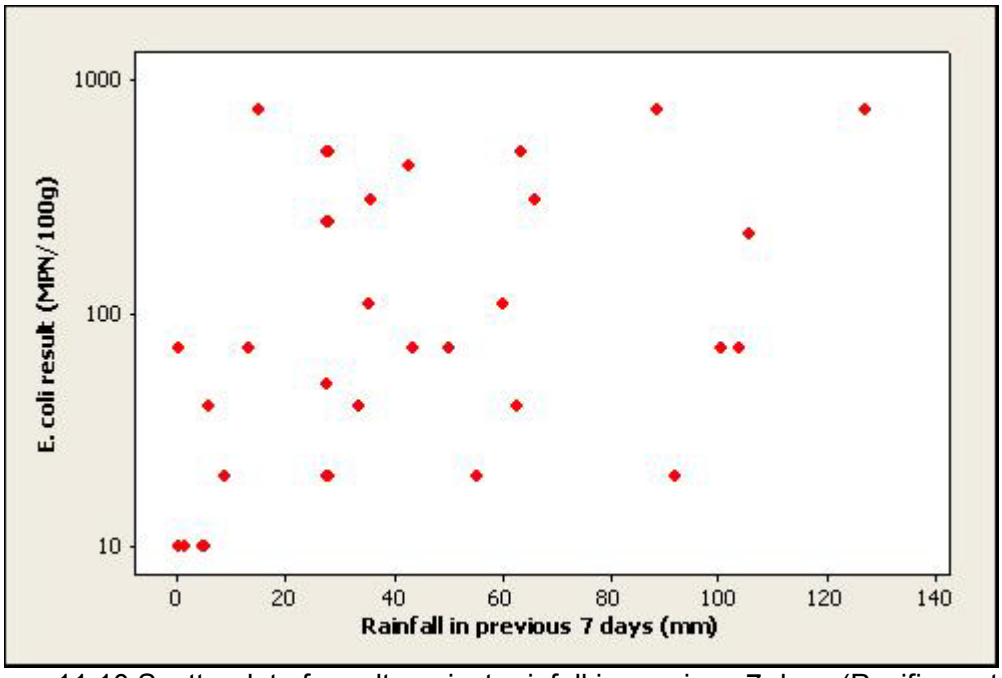


Figure 11.10 Scatterplot of result against rainfall in previous 7 days (Pacific oysters from Sgeirean Buidhe)

A positive correlation was found between *E. coli* results and rainfall in the previous 7 days (Spearman's rank correlation=0.431, p=0.017, Appendix 6).

11.6.2 Analysis of results by tidal height and state

Spring/Neap tidal cycles

When the larger (spring) tides occur every two weeks, circulation of water and particle transport distances will increase, and more of the shoreline will be covered at high water, potentially washing more faecal contamination from livestock into the loch. Figure 11.11 presents a polar plot of $\log_{10}$ *E. coli* results on the lunar spring/neap tidal cycle for Pacific oysters from Sgeirean Buidhe. Full/new moons are located at 0º, and half moons are located at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of under 230 *E. coli* MPN/100 g are plotted in green, those between 230 and 1000 *E. coli* MPN/100 g are plotted in yellow, and those over 1000 *E. coli* MPN/100 g are plotted in red. It should be noted that local meteorological conditions such as wind strength and direction can influence the height of tides and this is not taken into account.

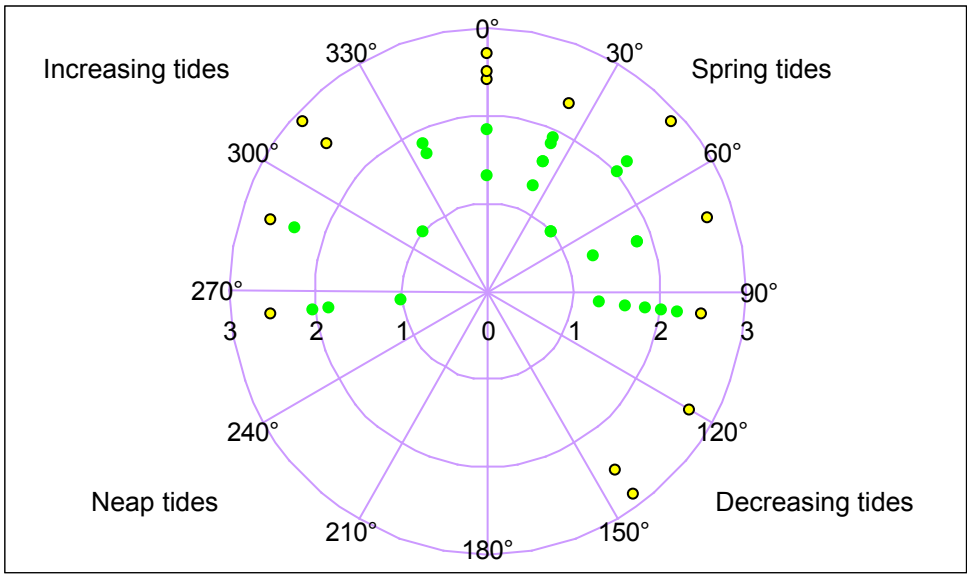


Figure 11.11 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle (Pacific oysters from Sgeirean Buidhe)

No significant correlation was found between *E. coli* results and the spring/neap cycle was found(circular-linear correlation, r=0.233, p=0.134, Appendix 6). Sampling was targeted towards the larger tides and no samples were taken in the lowest quadrant on decreasing to neap tides.

High/Low tidal cycles

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on

the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the farms during this cycle. As *E. coli* levels in some shellfish species can respond within a few hours or less to changes in *E. coli* levels in water, tidal state at time of sampling (hours post high water) was compared with *E. coli* results. Figure 11.12 presents a polar plot of $\log_{10}$ *E. coli* results on the lunar high/low tidal cycle for Pacific oysters from Sgeirean Buidhe. High water is located 0º, and low water at 180º. Again, results of under 230 *E. coli* MPN/100 g are plotted in green, those between 230 and 1000 *E. coli* MPN/100 g are plotted in yellow, and those over 1000 *E. coli* MPN/100 g are plotted in red.

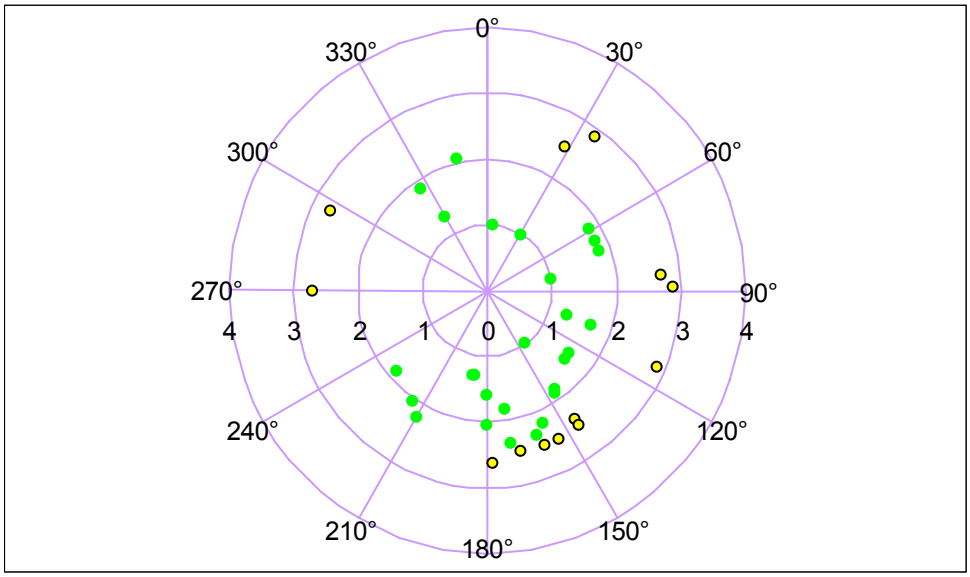


Figure 11.12 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle (Pacific oysters from Sgeirean Buidhe)

No significant correlation was found between *E. coli* results and the high/low tidal cycle was found (circular-linear correlation, r=0.124, p=0.565, Appendix 6). Sampling effort and results greater than 230 *E. coli* MPN/100 g appeared to be concentrated on the ebbing tide.

11.6.3 Analysis of results by water temperature

Water temperature is likely to affect the survival time of bacteria in seawater (Burkhardt *et al*, 2000) and the feeding and elimination rates of shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. It is of course closely related to season, and so any correlation between temperatures and *E. coli* levels in shellfish flesh may not be directly attributable to temperature, but to other factors such as seasonal differences in livestock grazing patterns. Figure 11.13 presents a scatterplot of *E. coli* results against water temperature for Pacific oysters from Sgeirean Buidhe.

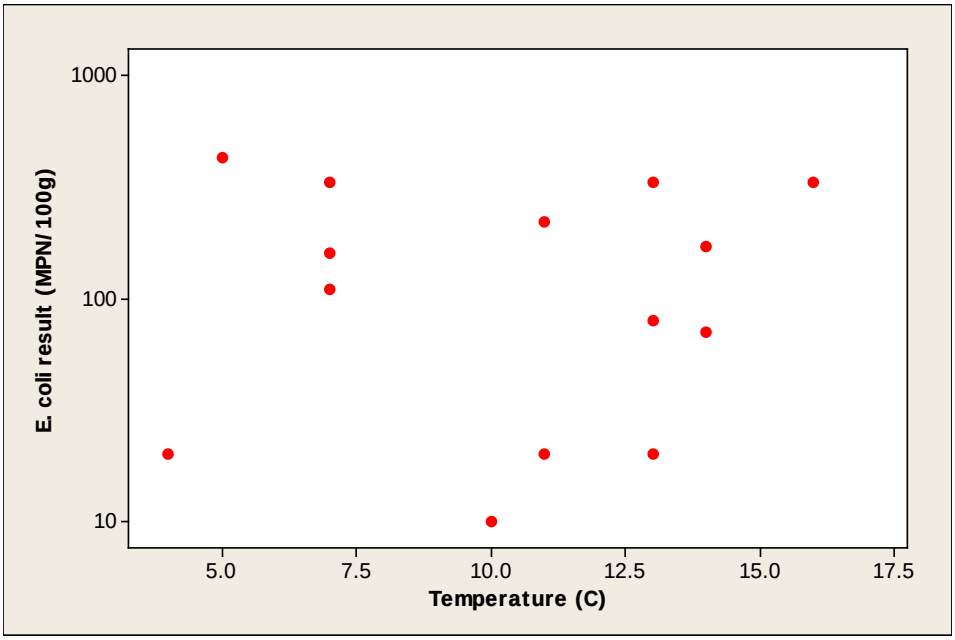


Figure 11.13 Scatterplot of result by water temperature (Pacific oysters from Sgeirean Buidhe)

The coefficient of determination indicates that there was no relationship between *E. coli* results and water temperature (Adjusted R-sq=0.0%, p=0.891, Appendix 6). The data appear to break between 7.5 and 10ºC, but again temperature was recorded for relatively few samples.

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 72 km to the south-west of the production area. 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 Arisaig 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 11.14 presents a scatterplot of *E. coli* result against salinity for Pacific oysters from Sgeirean Buidhe.

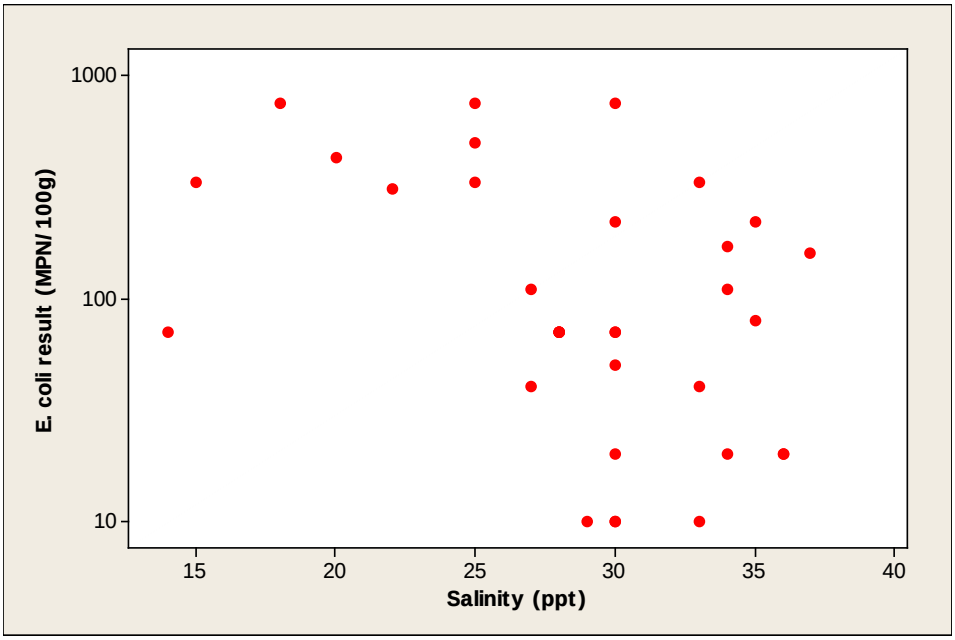


Figure 11.14 Scatterplot of result by salinity (Pacific oysters from Sgeirean Buidhe)

The coefficient of determination indicates that there was a weak negative relationship between salinity and *E. coli* result (Adjusted R-sq=14.6%, p=0.015, Appendix 6). Results less than 20 *E. coli* MPN/100 g were only found at salinities greater than 25 ppt.

11.7 Evaluation of peak results

No Pacific oyster samples from Arisaig had results >1000 *E. coli* MPN/100 g. Three mussel samples and one carpet clam sample returned results greater than this, however neither of these species is currently harvested within this production area.

11.8 Summary and conclusions

Geographic patterns were seen at Sgeirean Buidhe, where oysters taken from the west side of the trestles appeared to have higher results than those taken from the east side. The two highest results arose in consecutive months in 2002 at the North Channel site, suggesting there were relatively high levels of contamination present at the time.

From 2002, results for mussels from Loch nan Ceol deteriorated overall, with more frequent higher results occurring from 2004 onwards. During the same time period, aside from one high result in 2002, results for carpet clams from North Channel showed low levels of contamination throughout the sampling history. Results for Pacific oysters from Sgeirean Buidhe showed more of a cyclical trend, though very high and very low results were more common prior to 2007. No clear seasonal pattern in results or relationship between *E. coli* levels and temperature was found for any of the three site/species combinations investigated.

Positive correlations were found between *E. coli* result in Pacific oysters and recent rainfall, which is consistent with the location of the site near to a stream. Weak to very weak negative relationships between *E. coli* results and salinity were found, which broadly concurs with the positive correlations found with rainfall.

No statistically significant correlation was found between *E. coli* results and the spring/neap tidal cycle, however it must be noted that sampling effort was targeted toward spring tides thereby skewing the observations. Although no significant correlation was found with the high/low tidal cycle, both sampling effort and results >230 *E. coli* MPN/100 g appeared to be concentrated on the ebbing 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. This is not appropriate for Pacific oysters within this production area they have held seasonal classifications for the last three years. The area is currently declassified for the harvest of carpet clams and mussels.

12. Designated Shellfish Growing Waters Data

Loch nan Ceall does not coincide with a designated Shellfish Growing Water.

13. Rivers and Streams

There are no gauging stations on rivers or burns in the Arisaig: Loch nan Ceall area.

The streams listed in Table 13.1 were measured and sampled during the shoreline survey. These represent the largest freshwater inputs to the survey area. The weather was dry immediately prior to measurement and sampling of streams 1 to 6. Overnight rain fell prior to the sampling of streams 7 to 16.

Table 13.1 Stream loadings for Arisaig

No	Grid Ref	Description	Width (m)	Depth (m)	Flow (m/s)	Flow (m^3/day)	*E.coli* (CFU/100ml)	Loading (*E.coli* per day)
1	NM 66030 86144	Stream	6	0.19[1] 0.25	0.444 0.085	27400	<100	$<2.7x10^{10}$
2	NM 65727 86745	Stream	0.95	0.16	0.051	670	100	$6.7x10^{8}$
3	NM 65712 86779	Stream	0.7	0.08	0.128	619	<100	$<6.2x10^{8}$
4	NM 65459 86677	Stream	1.05	0.06	0.143	778	800	$6.2x10^{9}$
5	NM 64313 86846	Stream	0.4	0.07	0.053	128	<100	$<1.3x10^{8}$
6	NM 64344 86691	Stream	0.7	0.06	0.018	64	<100	$<6.4x10^{7}$
7	NM 65373 85067	An Garbh-allt	1.2	0.39	0.24	9700	<100	$<9.7x10^{9}$
8	NM 65620 85509	Stream					<100	Not determined[2]
9	NM 64889 84663	Stream	1.6	0.14	0.078	1510	<100	$<1.5x10^{9}$
10	NM 64642 85037	Stream	1.5	0.09	0.124	1450	<100	$<1.4x10^{9}$
11	NM 63875 85259	Stream	0.15	0.04	0.678	351	<100	$<3.5x10^{8}$
12	NM 63820 85311	Waterfall/ Stream				1[3]	<100	$<1.4x10^{6}$
13	NM 62804 85181	Stream				43[3]	<100	$<4.3x10^{7}$
14	NM 62881 85230	Stream	0.85	0.09	0.258	1710	<100	$<1.7x10^{9}$
15	NM 64137 87811	Stream	0.34	0.06	0.275	485	<100	$<4.8x10^{8}$
16	NM 64374 88037	Stream	0.55	0.14	0.053	353	100	$3.5x10^{8}$

[1]The two halves of the stream had different depths/flows
[2]Stream was too small to measure
[3]Flow measured using graduated jug

The largest source of freshwater to the Loch nan Ceall is Brunery Burn, which discharges via The Canal into the head of the loch south of the village.

Other streams were distributed widely around the shores of the survey area. Most of the sampled streams returned results of <100 *E. coli* cfu/100 ml. Actual loadings could not be calculated for these and the values are presented in the table as less than values. Samples from three streams (2, 4 and 16) returned quantifiable *E. coli* results, although two of these were 100 *E. coli* cfu/100 ml. Brunery Burn (Stream 4) returned a result of 800 *E. coli* cfu/100 ml which equated to a loading of 6.2×10^9 *E. coli*/day. This stream was located at the head of Loch nan Ceall. On its own it would not be expected to impact significantly on the microbiological quality of the present oyster trestles. However, the collective effect of all of the streams will be to contribute to background *E. coli* levels in the loch. More importantly, although streams 5, 6, 11 and 12 showed *E. coli* results below the limit of detection at the time of the shoreline survey, they are located immediately adjacent to oyster trestles and have the potential to impact on the microbiological quality of the shellfish, especially if the *E. coli* content increases significantly after heavy rain. The area of lines for suspended culture of oysters on the south-western side of Loch nan Ceall was the only part of the oyster farm not immediately adjacent to streams and thus would be expected to only be exposed to the general background contamination arising from seawater sources.

The points where the streams were measured and sampled, together with the calculated loadings, are shown in Figure 14.1. Where the bacterial loading is labelled on the map, the scientific notation is written in digital format, as this is the only format recognised by the mapping software. So, where normal scientific notation for 1000 is 1×10^3, in digital format it is written as 1E+3.

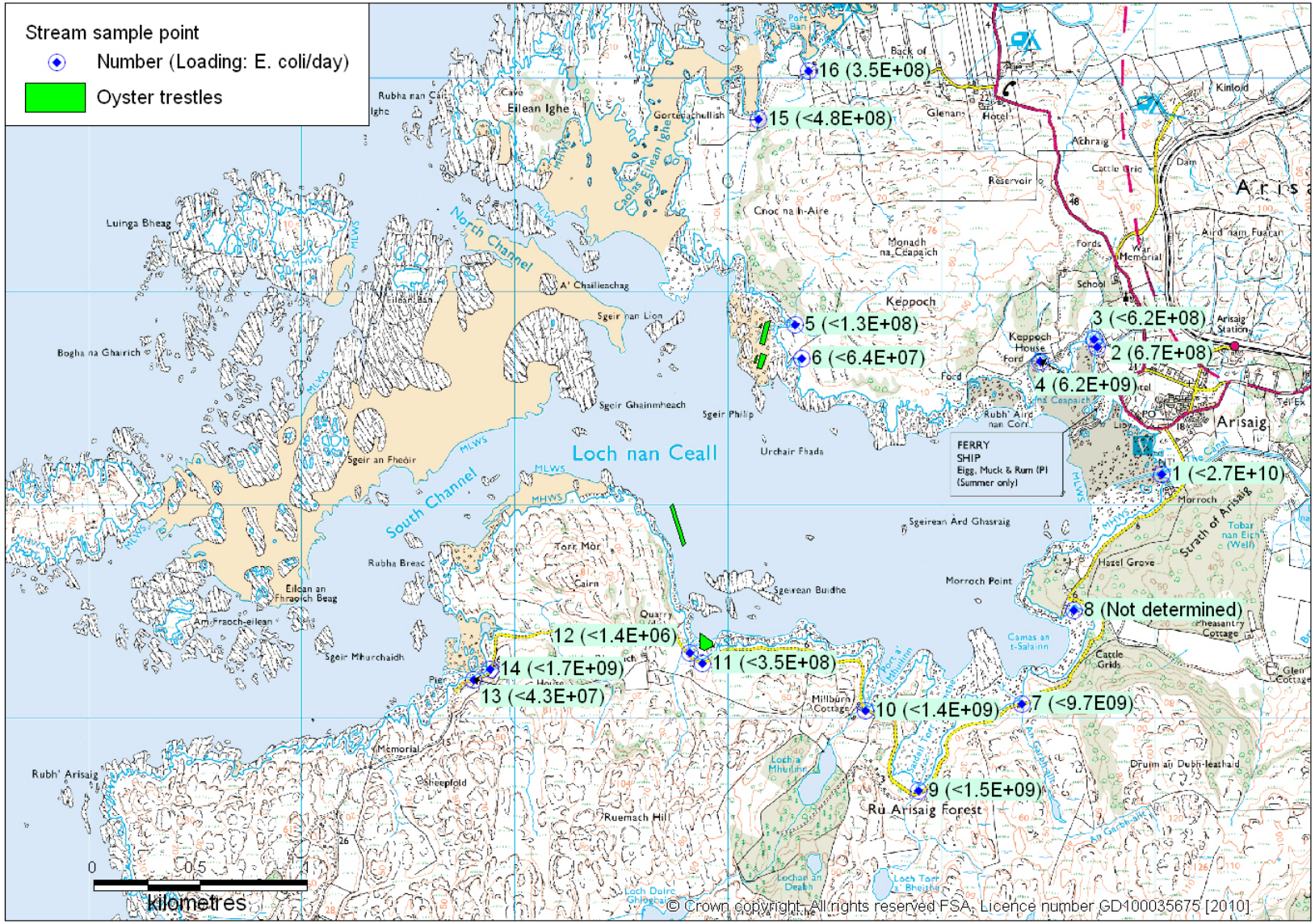


Figure 13.1 Stream loadings at Arisaig

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 nan Ceall and Figure 14.2 shows the bathymetry of the loch.

Figure 14.1 OS map of Loch nan Ceall

Figure 14.2 Bathymetry of Loch nan Ceall

Loch nan Ceall is approximately 3 km long and 1 km wide and runs in a north-west to south-east direction, with its mouth at the north-west end. The mouth is obstructed by numerous islands and a sand bar. The latter is exposed at low tide. Channels run either side of the sand bar, with the south channel being broader than the north.

There is a small deep near the mouth of the loch that is approximately 200 m in diameter and is 15.6 m at its deepest. The depth reduces away from this and is less than 5 m across much of the loch. The Scottish Sea lochs Catalogue identifies the presence of a sill across the south channel with a maximum depth at low water of 2 m (Edwards & Sharples, 1986). In addition to the sand bar at the mouth, there are significant drying areas around the edge of the loch – the Scottish Sea Lochs Catalogue indicates that 10% of the area of the loch is intertidal. At the time of the shoreline survey, all but one of the oyster trestle areas were located in or across the drying areas. The other was located below mean low water springs (MLWS).

14.1 Tidal Curve and Description

The two tidal curves illustrated in Figure 14.3 are for Malliag, approximately 11 km to the north of Loch nan Ceall. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 GMT on 20/10/09 and the second is for seven days beginning 00.00 GMT on 26/10/09. 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 Mallaig from TotalTide:

0353A Mallaig is a Secondary Non-Harmonic port.
The tide type is Semi-Diurnal.

HAT	5.6 m
MHWS	5.0 m
MHWN	3.6 m
MSL	2.98 m
MLWN	2.1 m
MLWS	0.8 m
LAT	0.0 m

Predicted heights are in metres above Chart Datum.
The tidal range at spring tide is therefore approximately 4.2 m and at neap tide 1.5 m.

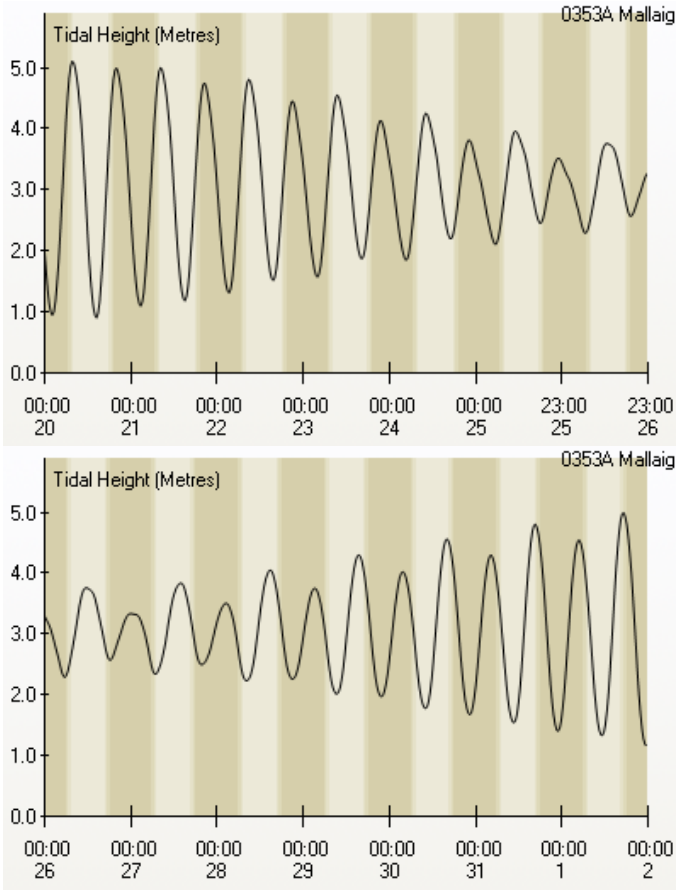


Figure 14.3 Tidal curves at Mallaig

14.2 Currents

No tidal stream locations were available on Totaltide for the area around Arisaig. The Admiralty Tidal Stream Atlas (UKHO, 1995) shows relatively weak tidal streams along the cost outside Loch nan Ceall. These tend to flow northwards parallel to the cost during the flood tide and southwards parallel to the coast during the ebb tide. Scottish Sea Kayaking (Cooper & Read, 2005) indicates that the average currents in both the north and south channels are 1 to 2 knots at spring tide (0.5 to 1 m/s). The neap tide currents would be expected to be approximately half of this. The Clyde Cruising Club sailing directions for the area identify that the tidal currents are strongest at the entrance during the last quarter of the ebb and the first quarter of the flood (Clyde Cruising Club, 2006).

14.3 Conclusions

Tidal currents in the mouth of the loch are in the order of 0.5 to 1 m/s on spring tides. They will be approximately half that value on neap tides. On the flood tide, currents will flow along the coast from the south and into the loch. On the ebb tide, currents will flow out of the loch and then southwards. Within

the loch, it is expected that currents will flow approximately parallel to the shore.

Sources of contaminants along the coast to the south of the loch may therefore be taken into the loch on the flooding tide. Sources on the coast to the north of the loch would not be expected to enter it to any significant extent, although there is the possibility that contamination taken past the loch on the ebbing tide could be brought back in on the next flooding tide. This would be subject to significant dilution and would only need to be considered if major sources of contamination were situated there. Overall, given the broader and somewhat deeper nature of the south channel, it would be expected that a larger volume of water will pass through it on a tidal cycle than through the north channel. However, this effect may be reduced by the presence of the sill in the south channel.

Contamination from sources towards, or at the head of the loch, would be expected to impact on the areas of oyster trestles on the ebbing tide. Given the limited depth within the loch, there will not be much dilution of any contamination. However, the moderate tidal range means that much of the contamination entering the loch will be removed during the tidal cycle – the Scottish Sea Lochs catalogue identifies that the loch has a flushing time of 0 days.

The oysters on the trestles in the intertidal areas will only be subject to potential contamination over part of the tidal cycle, when they are immersed. The extent of time that they are not covered by water towards and at low tide will depend on their location with respect to mean low water springs and mean low water neaps, together with the height of the trestles.

15. Shoreline Survey Overview

The shoreline survey was conducted on the 20th to 22nd October 2009. Rain fell overnight on the 21st, but otherwise the survey days were dry.

There were two Pacific oyster farms located within the area. A large area consisting of four discrete blocks of single tier wire and double timber trestles was situated on the north shore of the loch near Sgeir Philip. Stock was grown in mesh bags and most was not large enough for sampling. A stream discharged into the two northernmost sets of trestles.

The second farm was located on the southwestern shore of the loch, south of Sgeirean Buidhe and consisted of an area of single tier wire trestles with mostly mature stock. A stream discharged through the western side of the block of trestles. An area of mussel lines located off Tor Mór are currently used for bringing on immature Pacific oysters, which are then moved onto the Sgeirean Buidhe site. No mussels are produced at either site.

Population in the area was centred around the village of Arisaig at the head of the loch. Two septic tanks were observed at Arisaig, one of which did not appear to be in use. A third septic tank was located at the boatyard, which appeared to serve shore facilities associated with the harbour, which included a café and showers.

Further homes with private discharges were found south of the village around the headland at Morroch Point. Some of these discharges were highly contaminated, indicating septic content at the time of sampling (94000->100000 *E. coli* cfu/100 ml). A clay pipe was found leading to a stream near Milburn cottage, however this was not found to be in use at the time.

In the harbour, 14 boats were observed on moorings. A small ferry and wildlife tour boat provides transport to the Small Isles from a jetty near the village throughout the tourist season. During the summery, the harbour can accommodate over 90 yachts, most on moorings.

Sheep and sheep faeces were observed on the south shore of the loch between Morroch Point and Port a'Mhuilinn. Cattle (4) were observed at the cattle grid at Camas an t-Salainn and cattle tracks and faeces were found along the footpath between Arisaig and the trestles at Sgeir Philip. The harvester also noted that he keeps approximately 80 head of cattle upstream of the canal on the south side of the village.

Four seals were seen, three together at Morroch Point and a fourth at the south side of Camas an t-Salainn. Swans, ducks and shorebirds were observed and/or heard on a small skerry just offshore from where the fourth seal was spotted.

There were campgrounds and caravan sites north of Arisaig, near Back of Keppoch. No discharges were observed from these.

Most of the freshwater samples taken during the survey contained <100 *E. coli* cfu/100 ml. A sample from a stream north of the village was found to contain 800 *E. coli* cfu/100 ml, indicating moderate levels of faecal contamination. Three samples taken from discharge pipes at Morroch Point were highly contaminated. Seawater samples contained between 2 and 80 *E. coli* cfu/100 ml, indicating low to moderate levels of faecal contamination. The highest result was found at Camas an t-Salainn. The next highest (21 *E. coli* cfu/100 ml) was found next to the boatyard at Arisaig. Concentrations found at the fisheries were higher at Sgier Philip (15 *E. coli* cfu/100 ml) than at Sgeirean Buidhe (2 *E. coli* cfu/100 ml). One of the Pacific oyster samples taken from the Sgier Philip site also contained higher concentrations of E. coli (330 and 50 MPN/100 g) that those taken from Sgeirean Buidhe (50 and 70 MPN/100 g).

The most significant observations from the shoreline survey are mapped in Figure 15.1.

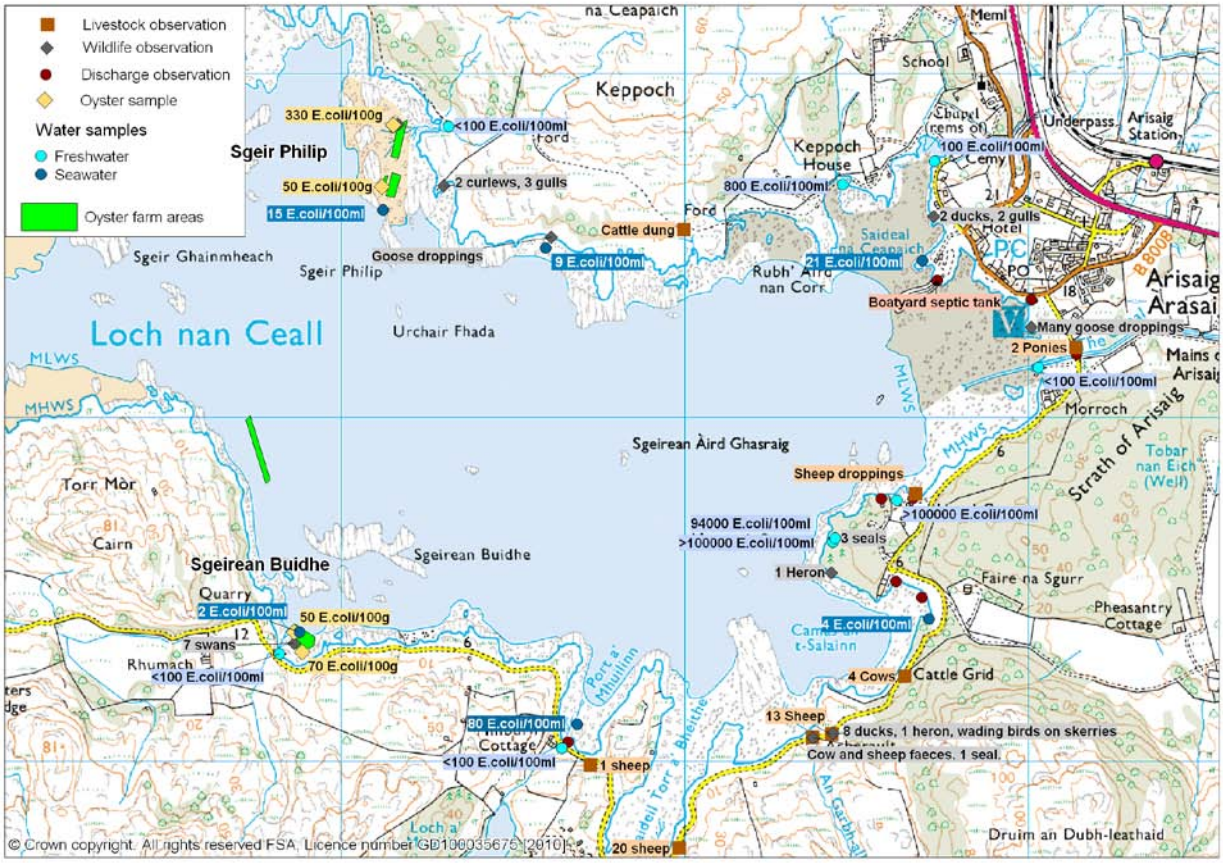


Figure 15.1 Summary of shoreline survey findings at Arisaig

16. Overall Assessment

Human sewage impacts

Population on the shores of Loch nan Ceall is low, and centred around the small community of Arisaig (population roughly 350) located at the head of the loch. At Arisaig, there is a single consented discharge from a Scottish Water septic tank with a PE of 250, which falls short of the estimated population of the area. Two further consents were provided by SEPA for small discharges to soakaway, both of which were located well away from the shoreline at Loch nan Ceall. A further septic tank was found at the boatyard jetty, near the village that served shoreside facilities including a café and showers. No discharge pipe was located. Given the proximity to the shore and limited space for a soakaway field, it is not clear where this tank discharges. There is a substantial area of moorings, accommodating approximately 90 yachts, at the head of the loch. Overboard discharges from these are likely to constitute a significant source of faecal contamination to the head of the loch, particularly during the summer months when they are more likely to be fully occupied.

Five possible private septic discharges were observed along the shore south of the village during the shoreline survey and water samples from three of these indicated significant septic content. A holiday cottage was found nearer to the Sgeirean Buidhe fishery and though a clay discharge pipe was dry, sewage fungus was found in a seep on the shore and a seawater sample from nearby contained and *E. coli* concentration consistent with moderate levels of faecal contamination (80 cfu/100 ml).

North of the loch, there are two campsites with caravan pitches located near Back of Keppoch. There is a SEPA consent for a private discharge to soakaway here, it is likely that this is associated with one of the homes in this area rather than the campsites. One possible septic tank was observed at the westernmost of the campsites, however no pipes were found and it is not clear whether it was in use. During the main tourist season, when these sites are likely to be more fully occupied, there could potentially be an increase in discharges of sewage to the marine environment north of the Sgeir Philip site.

Analysis of the historical monitoring data showed no particular seasonal trend in *E. coli* results, which seems to suggest that though there is likely to be a significant increase in human sewage discharge to the loch during the summer months, this does not appear to be driving increased levels of contamination found in the shellfish. This may be due in part to the location of the fisheries away from the head of the loch where discharges from the village and any moored boats are likely to have a higher impact. Although both sites are roughly the same distance from the village discharges, the Sgeirean Buidhe site is closer to discharges along the shore south of the village.

Agricultural impacts

The area around Loch nan Ceall does not host any known intensive agricultural operations and no arable fields were noted in the area. The Landcover2000 data indicated improved pasture around the village of Arisaig. This is consistent with observations made during the shoreline survey, which noted crofts and farms located inland from the village and also around the area of Back of Keppoch.The largest concentration of livestock noted during the survey were the 80 cattle that the harvester reported to keep upstream from the village. Faecal contamination carried in runoff from grazing areas and any hardstanding on farms is most likely to be carried to the bay via the Brunery Burn, which becomes The Canal before reaching the shoreline south of the village. A water sample collected from this location during the shoreline survey contained <100 *E. coli* cfu/100 ml, indicating low levels of contamination at the time, although the LOD used by the laboratory was relatively high.

Further cattle were observed south of the village and at Back of Keppoch. Sheep and their faeces were observed on the shoreline along the south shore of the loch while evidence of poaching by cattle was found along the banks of the stream that discharges through the northern end of the trestles at Sgeir Philip, which indicates that this stream may receive significant contamination from cattle faeces when the animals are present. Although the water sample taken from this stream during the shoreline survey contained fewer than 100 *E. coli* cfu/100 ml, the oyster sample collected from this end of the trestles contained 330 *E. coli* MPN/100 g, which exceeds the Class A limit and is indicative of moderate faecal contamination.

Faecal contamination from livestock observed along the south shore of the loch would be more likely to impact at the Sgeirean Buidhe site, particularly if and when grazing occurred on land drained by the stream that discharges across the area of trestles. However, no livestock were observed near the stream during the shoreline survey and the seawater sample taken from near where they discharge into the loch showed low levels of contamination.

Wildlife impacts

Seals were observed along the southern shore of the loch and hauled out on rocks near Sgeirean Buidhe during the shoreline survey. Given the proximity of the hauled out animals to the fishery, it is likely that seals contribute to background levels of faecal contamination present in the water there. However, sample results (both water and oyster) taken during the shoreline survey indicate that overall contamination levels present were relatively low despite the presence of the animals.

Deer are likely to be present in large numbers, however in the absence of more specific information on their distributions this loading will be assumed to be uniform around the loch.

Wildfowl were observed on the rocks offshore of the Sgeiran Buidhe site during the shoreline survey. Droppings were observed at locations around the shoreline of the loch, indicating that these birds were present across a wide area though droppings were particularly numerous to the south of the village.

Faecal material from the seabird nesting sites along the outer south channel are most likely to impact the longline site, though the impact is anticipated to be very low due to the small numbers of animals.

Overall, more wildlife appears to be present along the south shore of the loch and around the Sgeirean Buidhe site, therefore wildlife may make a larger contribution to background levels of contamination found in seawater around this area.

Seasonal variation

Human impact to the area is likely to be higher during the summer months, especially July and August when tourist numbers peak. Seabirds are more likely to be present on nests in the area during the early summer months, while wading birds and migratory waterfowl are more likely to be present during the autumn and winter, generally. Seals were present during the shoreline survey, which was undertaken in autumn. It is not known whether they are present near the fishery at all times of year.

While there is likely seasonal variation in sources of faecal contamination, no significant seasonal patterns were seen in *E. coli* monitoring results at any of the sites.

Analysis of historical rainfall data also indicated no clear seasonal pattern, therefore there is unlikely to be a clear seasonal pattern in rainfall-dependent sources, such as the diffuse sources located around the loch.

Rivers and streams

Freshwater courses discharging into the loch are widely distributed around the shores and the collective effect of these will be to contribute to background levels of *E. coli* in the loch. Of greatest significance to the fishery are the streams that discharge directly into the trestle areas. The stream discharging into the fishery at Sgeir Philip drains an area used to graze cattle and potentially other livestock, and evidence of cattle utilizing the stream was observed during the shoreline survey. A water sample taken from this stream at the time of survey contained <100 E. coli/100 ml, and an oyster sample taken from near the stream contained 330 E.coli/100, the latter indicating moderate levels of contamination.

The stream discharging into the trestles at Sgeirean Buidhe also was found to contain < 100 E. coli/100 ml, however *E. coli* concentrations in both seawater and shellfish were found to be lower than at the Sgeir Philip site, indicating

that the concentration in the stream was also likely to have been lower at the time.

Only the suspended culture site north of Sgeirean Buidhe did not receive direct input from a stream.

Meteorology, hydrography, and movement of contaminants

Predicted tidal currents within Loch nan Ceall are relatively weak and a combination of shallow depths (less than 5 m over much of the loch) and moderate tidal range (4.2 m springs) will result in more or less complete flushing of the loch with each tide, particularly at spring tides. Potential for dilution of contaminants entering the loch is limited by the water volume present, and contaminants taken out of the loch across the oyster farms with each ebb tide may to some extent wash back in on the following flood. The oyster trestles on the intertidal areas will only be subject to potential contamination over the part of the tidal cycle during which they are under water. The amount of exposure will vary within sites as some trestles are higher up the shore and others near or below MHWS. Oysters growing in suspended culture would be affected over all parts of the tidal range and so may accumulate greater levels of faecal contaminants than their intertidal counterparts. However, the suspended culture site is used for growing of immature oysters which are placed onto the trestles for growing on to market size.

Correlation was found between *E. coli* monitoring results in Pacific oysters and rainfall during the 2-day and 7-day periods prior to sampling. No similar correlation was found between results for either common mussels or carpet clams and rainfall. This may in part be due to the differences in accumulation of contaminants between the species, however it may also be due to the physical location of the oyster trestles. Trestles on both the north and south shores of the loch have streams running directly across them, which was consistent with the positive correlations found with rainfall. A weak correlation found between salinity and *E.coli* results in Pacific oysters also suggests fresh water as a significant source of faecal contamination to the fishery at Sgeirean Buidhe.

Temporal and geographical patterns of sampling results

Historical monitoring results in Pacific oysters showed some cyclical variation between 2005 and early 2010, though this did not appear to correlate directly with years or seasons. There have been no results >500 *E.coli* MPN/100 g since September 2006 and overall contamination levels appear to have improved somewhat since 2004. Interestingly, the patterns observed in results for the three different species differed considerably and this may be indicative of different drivers of contamination in each of the fisheries.

Results of 230 *E. coli* MPN/100 g or greater occurred in all months except February and April. No significant difference was found between results by

season for Pacific oysters from Sgeirean Buidhe although the median result was higher in autumn than in other seasons. This again differed with the trend in mussels, which showed higher results in summer.

Geographically, results in Pacific oysters appeared to be higher for samples taken along the western side of the trestles at Sgeirean Buidhe, where the stream is located. Sampling results for mussels were reported from two locations, a nominal RMP and a point corresponding to the southern end of the lines in use for suspended oyster culture observed during the shoreline survey. These results appeared to be higher at the southern end of the line, however as the nominal RMP plots on land, it is not clear to what point on the fishery these results would relate.

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Conclusions

The most significant identified sources of contamination by sewage discharges are near the head of the loch, in the vicinity of the village of Arisaig and moorings associated with the boatyard. However, sampling results generally indicated that results at the oyster farms were higher where streams crossed the trestle areas at the western side of Sgeirean Buidhe and the northern end of Sgeir Philip. There was no clear seasonality in results, though the median result for Pacific oysters was higher in autumn than in other seasons while in mussels results appeared to be higher in summer, though this was not found to be statistically significant. Weak correlations were found with rainfall, indicating that rainfall-dependent sources such as runoff to streams are a significant source though perhaps not the only source of contaminants to the fishery. Sewage discharges to the area would not be rainfall dependent and would be significantly higher in summer when there are more visiting yachts using the moorings.

Due to the shallow depths and tidal range at Loch nan Ceall, the majority of its water turns over with each tide flushing any contaminants from the head of the loch across the oyster sites on each ebb tide.

As the Pacific oyster fishery currently holds a seasonal classification it was not appropriate to undertake a stability assessment to determine whether the production area was suitable for reduced sampling frequency.

17. Recommendations

Production area
Recommended production area boundaries are the area bounded by lines drawn between NM 6270 8750 and NM 6384 8714 and between NM 6435 8651 to NM 6437 8539 extending to MHWS.

The recommended area covers the current oyster fishery but excludes the head of the loch where there were sewage discharges.

RMP
It is recommended that the RMP be relocated to NM 6387 8535. This will detect the contamination from the various sources in the area and will specifically detect any contamination arising from the stream discharging across the western side of the trestles.

Tolerance
A standard sampling tolerance of 10 m is recommended to allow for some variation in GPS recording accuracy.

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 Arisaig: Loch nan Ceall are shown mapped in Figure 17.1.

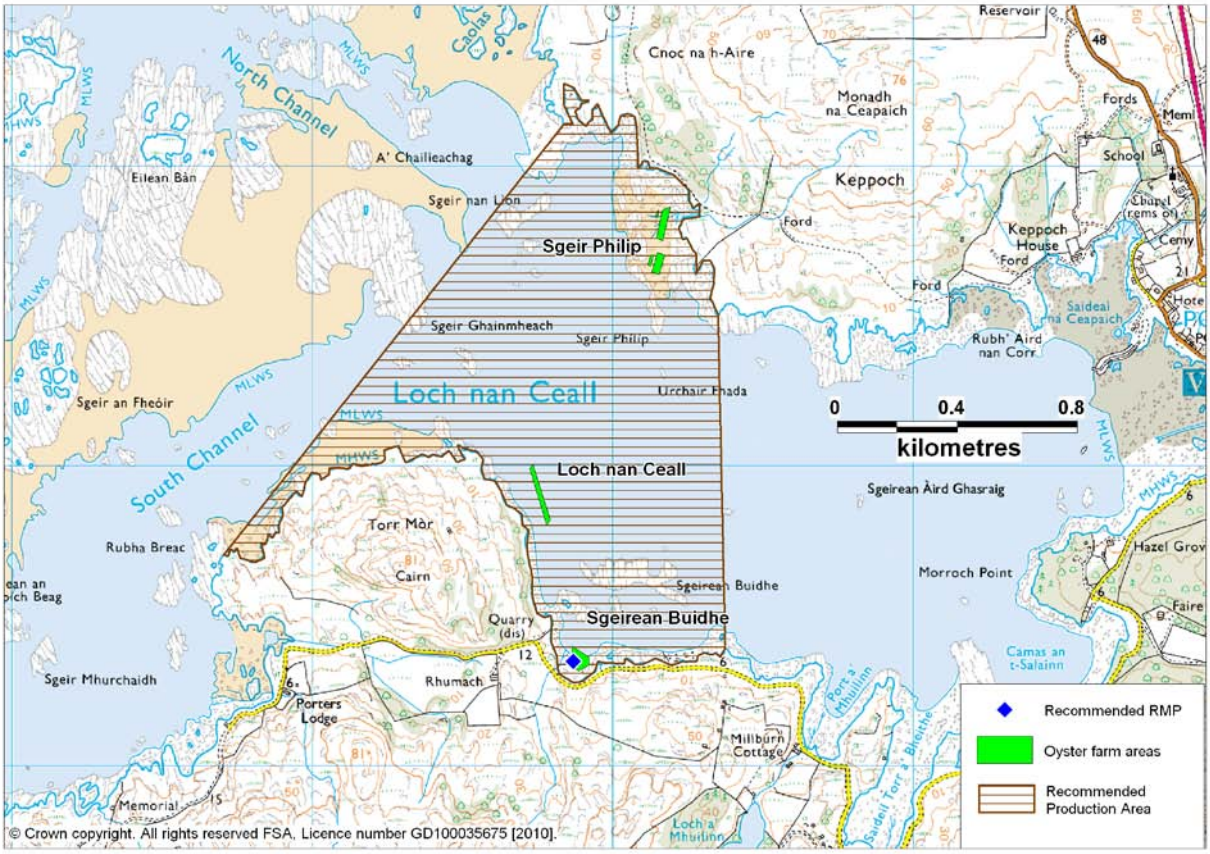

Figure 17.1 Recommendations for Arisaig: Loch nan Ceall

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Sampling Plan for Arisaig

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
Arisaig: Loch nan Ceall	Sgeirean Buidhe	HL 004 202 13	Pacific oyster	Trestle	NM 6387 8535	163870	785350	10	N/A	Hand	Monthly	Highland Council (Lochaber)	Stephen Lewis	Stephen Lewis

Table of Proposed Boundaries and RMPs

Production Area	Species	SIN	Existing Boundary	Existing RMP	New Boundary	New RMP	Comments
Arisaig: Loch nan Ceall	Pacific oyster	HL 004 202 13	Area bounded by lines drawn between NM 6291 8800 to NM 6000 8800 then to NM 6000 8400 and NM 6141 8400 then to NM 6500 8644 and NM 6496 8519 and between NM 6378 8783 and NM 6363 8783	NM 636 859 NM 638 853	Area bounded by lines drawn between NM 6270 8750 and NM 6384 8714 and between NM 6435 8651 to NM 6437 8539 extending to MHWS	NM 6387 8535	Area reduced to exclude areas not in use. Single RMP set at Sgeirean Buidhe to 10m accuracy.

Geology and Soils Assessment

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

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

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

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

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

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

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

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

These component soils were classed broadly into two groups based on whether they are freely or poorly draining. Drainage classes were created based on information obtained from the both the Macaulay Institute website

and personal communication with Dr. Alan Lilly. GIS map layers were created for each class with poorly draining classes shaded red, pink or orange and freely draining classes coloured blue or grey. These maps were then used to assess the spatial variation in soil permeability across a survey area and it's potential impact on runoff.

Glossary of Soil Terminology

Calcareous: Containing free calcium carbonate.

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

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

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

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

General Information on Wildlife Impacts

Pinnipeds

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

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

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

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

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

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

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

Cetaceans

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

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

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

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

Birds

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

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

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

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

Deer

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

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

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

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

Other

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

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

References:

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

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

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

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

Tables of Typical Faecal Bacteria Concentrations

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

Indicator organism	Base-flow conditions				High-flow conditions			
Treatment levels and specific types: Faecal coliforms	n^c	Geometric mean	Lower 95% CI	Upper 95% CI	n^c	Geometric mean	Lower 95% CI	Upper 95% CI
Untreated	252	1.7×10^{7} * (+)	1.4×10^{7}	2.0×10^{7}	282	2.8×10^{6} * (-)	2.3×10^{6}	3.2×10^{6}
Crude sewage discharges	252	1.7×10^{7} * (+)	1.4×10^{7}	2.0×10^{7}	79	3.5×10^{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	1.0×10^{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	3.3×10^{5} * (-)	2.9×10^{5}	3.7×10^{5}	184	5.0×10^{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	2.8×10^{5} * (-)	2.2×10^{5}	3.5×10^{5}	93	5.1×10^{5} * (+)	3.1×10^{5}	8.5×10^{5}
Oxidation ditch	35	2.0×10^{5}	1.1×10^{5}	3.7×10^{5}	5	5.6×10^{5}		
Trickling/sand filter	11	2.1×10^{5}	9.0×10^{4}	6.0×10^{5}	8	1.3×10^{5}		
Rotating biological contactor	80	1.6×10^{5}	1.1×10^{5}	2.3×10^{5}	2	6.7×10^{5}		
Tertiary	179	1.3×10^{3}	7.5×10^{2}	2.2×10^{3}	8	9.1×10^{2}		
Reedbed/grass plot	71	1.3×10^{4}	5.4×10^{3}	3.4×10^{4}	2	1.5×10^{4}		
Ultraviolet disinfection	108	2.8×10^{2}	1.7×10^{2}	4.4×10^{2}	6	3.6×10^{2}		

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

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

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

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

Statistical Data

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

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

```
Source  DF      SS     MS     F      P
Season   3   0.718  0.239  0.72  0.545
Error   36  11.926  0.331
Total   39  12.644

S = 0.5756   R-Sq = 5.68%   R-Sq(adj) = 0.00%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev   -+---------+---------+---------+--------
1      10  1.9271  0.6414      (-----------*-----------)
2      10  2.0163  0.4890         (-----------*-----------)
3      10  2.2107  0.5460               (-----------*-----------)
4      10  1.8522  0.6136   (-----------*-----------)
                           -+---------+---------+---------+--------
                          1.50      1.80      2.10      2.40

Pooled StDev = 0.5756
```

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

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = 0.400
P-Value = 0.029
```

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

```
Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.431
P-Value = 0.017
```

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 24 November 2009 16:10:59

Variables (& observations)	r	p
Angles & Linear (40)	0.233	0.134

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 24 November 2009 16:10:14

Variables (& observations)	r	p
Angles & Linear (40)	0.124	0.565

.

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

```
The regression equation is
log e coli for temperature = 1.91 + 0.0059 temperature


Predictor       Coef  SE Coef     T      P
Constant      1.9145   0.4624  4.14  0.001
temperature  0.00590  0.04215  0.14  0.891


S = 0.570523   R-Sq = 0.2%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF      SS      MS     F      P
Regression       1  0.0064  0.0064  0.02  0.891
Residual Error  12  3.9060  0.3255
Total           13  3.9123
```

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

```
The regression equation is
log e coli for salinity = 3.14 - 0.0416 salinity


Predictor      Coef  SE Coef      T      P
Constant     3.1422   0.4731   6.64  0.000
salinity   -0.04158  0.01612  -2.58  0.015


S = 0.533572   R-Sq = 17.2%   R-Sq(adj) = 14.6%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   1.8938  1.8938  6.65  0.015
Residual Error  32   9.1104  0.2847
Total           33  11.0041


Unusual Observations

                 log e coli
Obs  salinity  for salinity     Fit  SE Fit  Residual  St Resid
 21      14.0        1.8451  2.5602  0.2554   -0.7151     -1.53 X
 28      15.0        2.5185  2.5186  0.2405   -0.0001     -0.00 X

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

Hydrographic Methods

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

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

Background processes

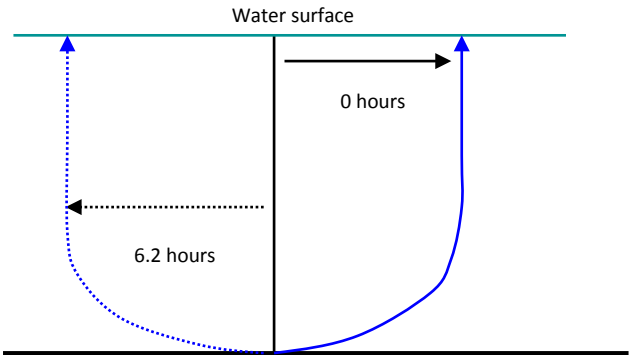
Currents in estuarine and coastal waters are generally driven by one of three mechanisms: 1) Tides, 2) Winds, 3) Density differences.

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

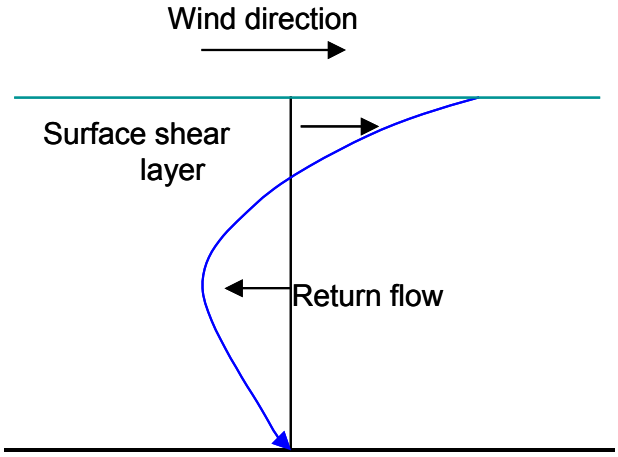
Wind and density driven current also lead to persistent movement of water and are particular important in regions of relatively low tidal velocities characteristic of many of the water bodies in Scottish waters. Whilst tidal flows generally move material in more or less the same direction at all depths,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

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

a)



b)



c)

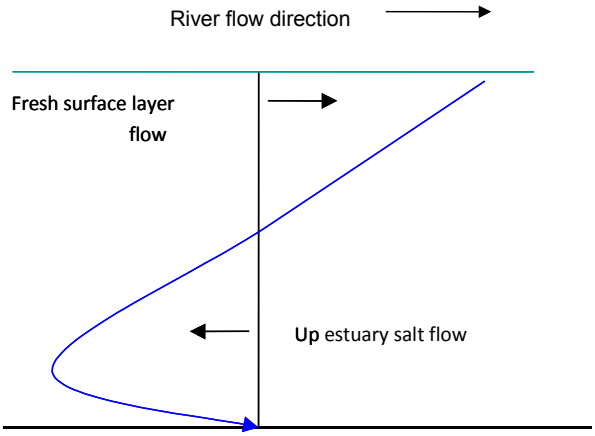


Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

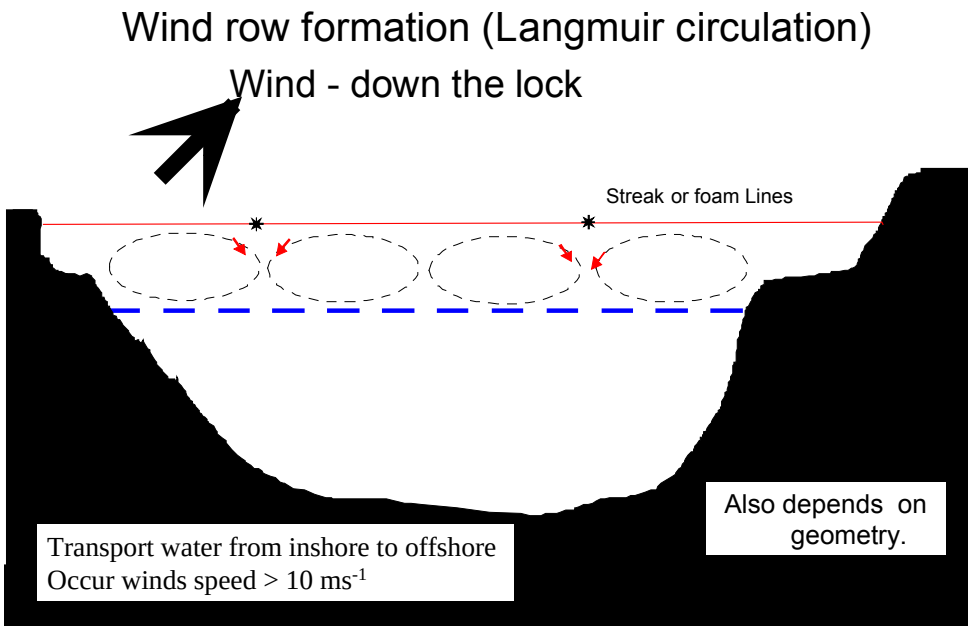


Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Non-modelling Assessment

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

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

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

The catalogue of Scottish Sea Loch produced by the SMBA is used to quantify sills, volume fluxes and likely flow velocities. Because the flow is so constrained by the rapidly varying bathymetry, care has to be used in the extrapolation of direct measurements of current flow. Mean flow velocities can be estimated at the sills by using estimates of the sill area and the volume change through a tidal cycle. This in turn can be used to estimate the

maximum distance travelled in a tidal cycle in the sill area. Away from the sill area, tidal velocities are general low and transport events are dominated by wind or density effects. Sea Lochs generally have a surface layer of fresher water; the extent of this depends on freshwater input, sill depth and quantity of mixing.

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

References

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

Glossary

The following technical terms may appear in the hydrographic assessment.

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

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

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

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

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

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

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

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

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

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

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

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

Shoreline Survey Report

Arisaig
HL 004

Scottish Sanitary Survey Project

Production Area	Site	SIN	Species
Arisaig	Loch nan Ceol	HL 004 198 13	Pacific oyster
	Loch nan Ceol	HL 004 198 08	Common mussel*
	Sgeirean Buidhe	HL 004 202 13	Pacific oyster
	North Channel	HL 004 200 08	Common mussel

Harvester: James Colston
Local Authority: Highland Council, Lochaber
Status: New/Existing
Date Surveyed: 20-22 October 2009
Surveyed by: M. Price-Hayward, S. Lewis
RMPs: Sgeirean Buidhe NM 638 853, Loch nan Ceol NM 636 859
Area Surveyed: Loch nan Ceall, Arisaig and Back of Keppoch

Weather observations
20 Oct: Wind SE Force 5, gusting higher. Overcast and dry, air temp 11C.
21 Oct: Winds calm. Overcast. Rain overnight, air temp 10C.
22 Oct: Winds E Force 2. Clear to partly cloudy, dry, air temp 10C.

Specific survey observations are shown mapped in Figure 1 and are listed in Table 1. Below is a summary of those observations.

Fishery
Two Pacific oyster farms are located within the identified area. The larger of the two lies on the north shore of the entrance to Loch nan Ceall, near Sgeir Philip. This consisted of four discrete areas of wire single trestles and timber stacked trestles with oysters in flat plastic mesh bags or in traingular bags. Most of the stock was very small at the time of survey, with only limited areas with stock large enough for sampling.

The second farm was located on the southwestern shore of the loch, south of Sgeirean Buidhe. This consisted of a single area of wire trestles with stock of mature size.

Loch nan Ceol is not currently used for mussel production. The mussel lines located just off Torr Mòr are currently used for bringing on immature Pacific oysters which are then moved onto thSgeirean Buidhe. No mussels are harvested from the North Channel.

Periwinkles are harvested from the area, and a person was observed harvesting winkles from near the Sgeir Philip site (Figure 1, No. 19).

Sewage/Faecal Sources
There were two septic tanks located in the village of Arisaig. One, at the northern end of village next to a carpark, was apparently no longer in use. The second, located at the southern end of village was the main Scottish Water septic tank for the community. The discharge pipe, however, was not directly visible at the time.

There was a separate septic tank at the boatyard (Figure 1, No. 60). No discharge pipe was found for this tank, however the area in which it is installed hasn't much room for a soakaway. This tank appears to serve shore facilities associated with the harbour, which include a café and showers.

Further discharge pipes to shore were found around Morroch Point, where there were houses uphill from the shore. A private septic tank was found near the An Garbh-allt (Figure 1, No. 28), however no discharge pipe was found.

A hollow tank was found beneath the turf near Porters Lodge (Figure 1, No. 66), however it did not appear to be connected to the house and no discharge pipe was found so its purpose was unclear.

A number of livestock were observed in the area. Both sheep and sheep faeces were observed on the south shore of the loch between the north side of Morroch Point and Port a'Mhuilinn approximately 1km to the southwest. Recent cattle tracks and droppings were present on grassland along the footpath between Arisaig and the trestles at Sgeir Philip and cattle were observed at the cattle grid at Camas an t-Salainn (Figure 1, No. 32). The harvester also keeps approximately 80 cattle upstream from shore on the south side of village (Figure 1, No. 6). A farm and 13 cattle were observed at Back of Keppoch (Figure 1, No. 78).

Seasonal Population

There were a number of campground and caravan sites in the area, particularly to the north of Arisaig and around Back of Keppoch. These would be more fully occupied during the summer holiday months of June-August, however were relatively quiet on the survey dates. Some of the homes in the area appeared to be only seasonally occupied.

Boats/Shipping

There was a boat yard and harbour at Arisaig. According to the ferry manager, the harbour can accommodate over 90 yachts in summer, most on moorings. A small ferry and wildlife tour boat runs to the Small Isles from a jetty near the village (Figure 1, No. 61) through the tourist season.

Land Use

Much of the land in the area is rough grassland some of which is used for grazing livestock. There are crofts and farms inland of Arisaig and also to the north at Kinloid and Back of Keppoch.

Wildlife/Birds

Seals, swans, and various shorebirds were observed during the survey. Four seals were seen, three together at Marroch Point (Figure 1, No. 40) and a fourth at the south side of Camas an t-Salainn (Figure 1, No. 31). Swans, ducks and shorebirds were observed and/or heard on the small skerry just offshore from where the fourth seal was spotted.

Recorded observations apply to the date of survey only. Animal numbers were recorded on the day from the observer’s point of view. This does not

necessarily equate to total numbers present as natural features may obscure individuals and small groups of animals from view.

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

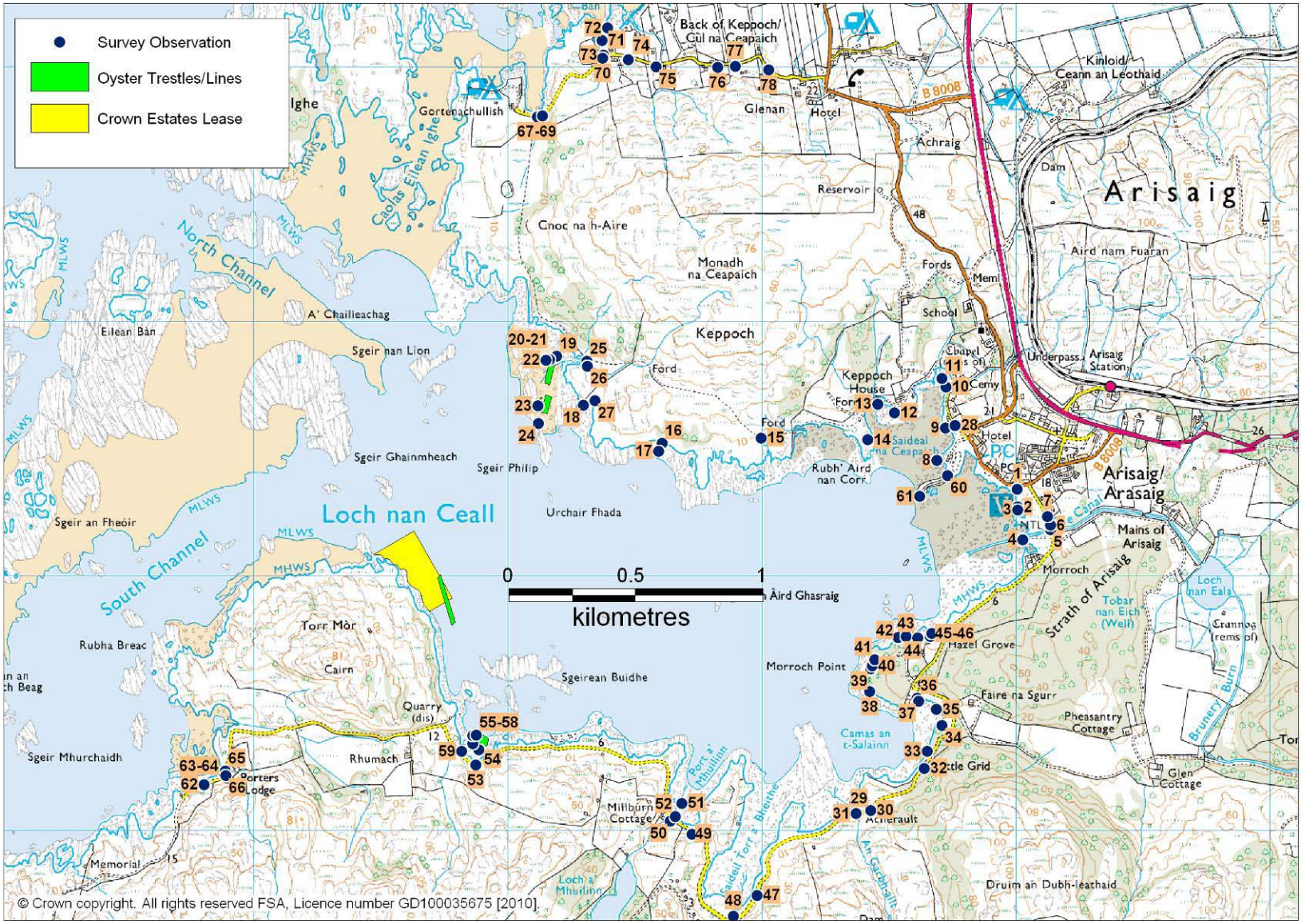


Figure 1 Map of Shoreline Observations

Table 1 Shoreline Observations

No.	Date	Time	Grid Ref	Eastings	Northings	Assoc. Photo-graph	Observation
1	20/10/2009	10:14:32	NM 66008 86342	166008	786342		Old septic tank - next to car park
2	20/10/2009	10:17:49	NM 66010 86272	166010	786272		Stinking water in reedbed
3	20/10/2009	10:19:16	NM 66009 86261	166009	786261		Many goose droppings
4	20/10/2009	10:29:04	NM 66030 86144	166030	786144		Stream 6x0.19x0.444m/s and 6x0.25x0.085m/s Water Sample ARG01
5	20/10/2009	10:42:54	NM 66139 86183	166139	786183	Figures 4, 5	New septic tank, old signage at roadside indicating Rhu Road PS (North of Scotland Water Authority)
6	20/10/2009	10:48:52	NM 66140 86201	166140	786201		2 Ponies. Harvester also has ~ 80 cattle upstream
7	20/10/2009	10:50:45	NM 66128 86234	166128	786234	Figure 6	End of main village
8	20/10/2009	11:07:33	NM 65691 86456	165691	786456	Figure 7	Boat Yard. Water Sample ARG02
9	20/10/2009	11:22:09	NM 65725 86584	165725	786584		2 ducks, 2 gulls
10	20/10/2009	11:28:57	NM 65727 86745	165727	786745		0.95x0.16x0.051m/sec. Water Sample ARG0 3
11	20/10/2009	11:36:12	NM 65712 86779	165712	786779		Stream 0.70x0.08x0.128m/sec. Water Sample ARG04
12	20/10/2009	11:48:07	NM 65524 86643	165524	786643		Derelict house. No discharge pipe found
13	20/10/2009	11:51:03	NM 65459 86677	165459	786677		Stream 1.05x0.06x0.143m/sec. Water sample ARG05
14	20/10/2009	12:01:40	NM 65419 86537	165419	786537		14 boats on mooring. SL reports 30-40 yachts in the summer
15	20/10/2009	12:14:32	NM 64999 86544	164999	786544		Cattle tracks and droppings (fresh)
16	20/10/2009	12:30:39	NM 64610 86524	164610	786524		Goose droppings
17	20/10/2009	12:32:14	NM 64595 86492	164595	786492		Seawater Sample water sample ARG06. Salinity 35ppt
18	20/10/2009	12:50:48	NM 64298 86673	164298	786673		2 curlews, 3 gulls
19	20/10/2009	13:01:55	NM 64194 86865	164194	786865	Figure 8	Pacific oyster farm near Sgeir Philip. Corner of trestle block 1. Cockles, clams and native oysters present on seabed in area. Person observed collecting winkles in the area.
20	20/10/2009	13:03:13	NM 64165 86852	164165	786852	Figure 9	Corner of trestle block 1. 4 oyster catchers 1 gull
21	20/10/2009	13:04:07	NM 64152 86854	164152	786854		Corner of trestle block 2 (larger oysters on bottom row, smaller on top)
22	20/10/2009	13:11:15	NM 64151 86850	164151	786850	Figures 10,11	Pacific oyster sample ARGSF1
23	20/10/2009	13:40:09	NM 64119 86670	164119	786670		Pacific oyster sample ARGSF2. Salinity 35ppt
24	20/10/2009	13:52:48	NM 64122 86602	164122	786602		Water sample ARG07
25	20/10/2009	14:08:11	NM 64313 86846	164313	786846		Stream 0.40x0.07x0.053m/sec. Area used by cattle. Water sample ARG08
26	20/10/2009	14:13:06	NM 64315 86826	164315	786826	Figure 12	Other branch of stream - barely flowing. Boggy - poached. Bright green algae on rocks downstream
27	20/10/2009	14:20:19	NM 64344 86691	164344	786691		Stream 0.70x0.06x0.0177m/sec. Water sample ARG09
28	20/10/2009	15:01:17	NM 65763 86594	165763	786594		Septic tank
29	21/10/2009	10:09:43	NM 65430 85077	165430	785077		13 Sheep

No.	Date	Time	Grid Ref	Eastings	Northings	Assoc. Photo-graph	Observation
30	21/10/2009	10:10:54	NM 65431 85079	165431	785079		8 ducks, 1 heron, quite a few wading birds on skerries ~20 oyster catchers
31	21/10/2009	10:15:05	NM 65373 85067	165373	785067	Figure 13	Stream An Garbh-allt. 1.20x0.39x0.24m/sec. Water sample ARG10. Numerous cow pats and sheep droppings. 1 seal. Swans heard on skerry
32	21/10/2009	10:30:10	NM 65641 85245	165641	785245	Figure 14	4 cows hanging around at cattle grid on road
33	21/10/2009	10:35:17	NM 65654 85311	165654	785311		Salinty 35ppt at shore
34	21/10/2009	10:44:09	NM 65711 85413	165711	785413		Very shallow stream, sea water sample taken. Water sample ARG11. Salinity 30ppt
35	21/10/2009	10:54:42	NM 65690 85476	165690	785476	Figure 15	Discharge pipe - clay. 13cm diameter - flowing. Water sample ARG12
36	21/10/2009	11:05:50	NM 65614 85521	165614	785521	Figure 16	Septic tank with overflow pipe
37	21/10/2009	11:07:43	NM 65620 85509	165620	785509	Figure 17	Small stream with possible sewage fungus. Water sample ARG13
38	21/10/2009	11:25:42	NM 65426 85547	165426	785547		1 Heron
39	21/10/2009	11:38:09	NM 65431 85637	165431	785637		Discharge pipe - clay. 13cm diameter - flowing. Water sample ARG14
40	21/10/2009	11:45:03	NM 65437 85647	165437	785647		Stream and pipe both flowing slightly. House above. Water sample ARG15. Flow 30ml/40secs. Odour. 3 seals
41	21/10/2009	11:57:55	NM 65447 85672	165447	785672		Bottom of garden with 3 small land drains
42	21/10/2009	12:09:17	NM 65539 85759	165539	785759		House
43	21/10/2009	12:12:22	NM 65571 85763	165571	785763		Discharge pipe. Smelly, active but not flowing at time of survey
44	21/10/2009	12:21:06	NM 65617 85758	165617	785758		Pipe dribbling - looks dirty. Water sample ARG16. Flow 30ml in appr 40sec
45	21/10/2009	12:30:04	NM 65665 85764	165665	785764		Septic pipe. Water sample ARG17. 30ml/2sec
46	21/10/2009	12:31:33	NM 65672 85775	165672	785775		Sheep droppings on shore
47	21/10/2009	13:00:19	NM 64984 84745	164984	784745		20 sheep on shore
48	21/10/2009	13:04:32	NM 64889 84663	164889	784663		Stream 1.6x0.14x0.078m/sec. Water sample ARG18
49	21/10/2009	13:11:27	NM 64726 84986	164726	784986		1 sheep on shore
50	21/10/2009	13:13:10	NM 64642 85037	164642	785037		Stream - holiday cottage. 1.5x0.09x0.124m/sec. Water sample ARG19
51	21/10/2009	13:26:35	NM 64686 85107	164686	785107		Sea water sample ARG20. Seep with sewage fungus on shore
52	21/10/2009	13:29:16	NM 64660 85055	164660	785055		Clay pipe to stream. No flow
53	21/10/2009	13:40:28	NM 63875 85259	163875	785259		Stream at culvert. 0.15x0.04x0.678m/sec. Water sample ARG21
54	21/10/2009	13:46:14	NM 63887 85317	163887	785317	Figures 18,19	Pacific oyster farm at SgeireanBuidhe. Corner of trestles. Stream runs across shore here. Pacific oyster sample ARGSF3. Shore mussels and winkles present
55	21/10/2009	14:19:26	NM 63859 85353	163859	785353	Figure 20	2nd stream crosses here. Salinty 5ppt
56	21/10/2009	14:20:51	NM 63863 85341	163863	785341		7 swans, these may have been the 'geese' heard in in No. 31.
57	21/10/2009	14:30:49	NM 63863 85374	163863	785374		Pacific oyster sample ARGSF4. No seawater sample taken
58	21/10/2009	14:35:48	NM 63878 85375	163878	785375		Water sample ARG22
59	21/10/2009	14:45:21	NM 63820 85311	163820	785311		Waterfall/stream. 21ml/2 sec. with sample flow over ~2/3 flow. Water sample ARG23. Seals hauled out offshore

No.	Date	Time	Grid Ref	Eastings	Northings	Assoc. Photo-graph	Observation
60	22/10/2009	09:35:37	NM 65734 86397	165734	786397	Figure 21	Septic tank at boatyard. No pipe apparent - tide in. Pipe also no visible at low tide
61	22/10/2009	09:42:16	NM 65623 86314	165623	786314	Figure 22	Small Isles Ferry. Harbour with 90+ yachts in during the summer. 75 or so moorings. Facilities for visiting yachts including café and showers.
62	22/10/2009	10:22:35	NM 62804 85181	162804	785181		Stream. 2l/4sec. Water sample ARG24
63	22/10/2009	10:29:58	NM 62881 85230	162881	785230	Figure 23	Stream 0.85x0.09x0.258m/sec. Water sample ARG25
64	22/10/2009	10:34:18	NM 62894 85230	162894	785230		House adjacent stream unoccupied - holiday let under renovation. Septic tank not seen
65	22/10/2009	10:37:17	NM 62889 85235	162889	785235		Road drain
66	22/10/2009	10:41:03	NM 62891 85217	162891	785217		Hollow tank under turf unknown. No pipe apparent from house to tank or from tank to shore
67	22/10/2009	11:12:01	NM 64116 87809	164116	787809		10 cattle
68	22/10/2009	11:19:35	NM 64118 87807	164118	787807		Tarmac to house about 100m uphill from point
69	22/10/2009	11:25:00	NM 64137 87811	164137	787811		0.34x0.06x0.275m/sec. Water sample ARG26. Large cow droppings
70	22/10/2009	11:36:22	NM 64374 88037	164374	788037	Figure 24	Stream 0.55x0.14x0.053m/sec. Water sample ARG27. 3 caravans, 50 small birds
71	22/10/2009	11:47:26	NM 64372 88108	164372	788108		11 further caravans lining beach. Large numbers of clam shells
72	22/10/2009	11:53:03	NM 64395 88156	164395	788156		Water sample ARG28. Salinity 33ppt
73	22/10/2009	12:07:32	NM 64378 88050	164378	788050		Possible septic tank with wood cover. Near caravan - no discharge pipes apparent
74	22/10/2009	12:49:52	NM 64475 88032	164475	788032		6 more static caravans. 4 cattle
75	22/10/2009	12:51:21	NM 64585 88004	164585	788004		4 houses, 1 static caravan
76	22/10/2009	12:52:34	NM 64829 88001	164829	788001		Derelict house. 2 occupied caravans. Shed
77	22/10/2009	12:53:13	NM 64897 88006	164897	788006		2 houses
78	22/10/2009	12:53:49	NM 65030 87992	165030	787992		Farm house. 13 cattle. Further houses and 1 caravan

Photos referenced in the table can be found attached as Figures 4-24.

Sampling

Water and shellfish samples were collected at sites marked on the map. Where indicated in Table 1, salinity was recorded in the field using a refractometer. Samples were transferred to coolboxes and shipped on the day collected to Glasgow Scientific Services for *E. coli* analysis. Bacteriology results follow in Tables 2 and 3.

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

Table 2 Water Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (cfu/100 ml)	Salinity (g/L)
1	20/10/2009	ARG 01	NM 66030 86144	Freshwater	<100	-
2	20/10/2009	ARG 02	NM 65691 86456	Seawater	21	35.1
3	20/10/2009	ARG 03	NM 65727 86745	Freshwater	100	-
4	20/10/2009	ARG 04	NM 65712 86779	Freshwater	<100	-
5	20/10/2009	ARG 05	NM 65459 86677	Freshwater	800	-
6	20/10/2009	ARG 06	NM 64595 86492	Seawater	9	35.6
7	20/10/2009	ARG 07	NM 64122 86602	Seawater	15	35.2
8	20/10/2009	ARG 08	NM 64313 86846	Freshwater	<100	-
9	20/10/2009	ARG 09	NM 64344 86691	Freshwater	<100	-
10	21/10/2009	ARG 10	NM 65373 85067	Freshwater	<100	-
11	21/10/2009	ARG 11	NM 65711 85413	Seawater	4	34.3
12	21/10/2009	ARG 12	NM 65690 85476	Freshwater	<100	-
13	21/10/2009	ARG 13	NM 65620 85509	Freshwater	<100	-
14	21/10/2009	ARG 14	NM 65431 85637	Freshwater	94000	-
15	21/10/2009	ARG 15	NM 65437 85647	Freshwater	>100000	-
16	21/10/2009	ARG 16	NM 65617 85758	Freshwater	>100000	-
17	21/10/2009	ARG 17	NM 65665 85764	Freshwater	<100	-
18	21/10/2009	ARG 18	NM 64889 84663	Freshwater	<100	-
19	21/10/2009	ARG 19	NM 64642 85037	Freshwater	<100	-
20	21/10/2009	ARG 20	NM 64686 85107	Seawater	80	32.2
21	21/10/2009	ARG 21	NM 63875 85259	Freshwater	<100	-
22	21/10/2009	ARG 22	NM 63878 85375	Seawater	2	34.3
23	21/10/2009	ARG 23	NM 63820 85311	Freshwater	<100	-
24	22/10/2009	ARG 24	NM 62804 85181	Freshwater	<100	-
25	22/10/2009	ARG 25	NM 62881 85230	Freshwater	<100	-
26	22/10/2009	ARG 26	NM 64137 87811	Freshwater	<100	-
27	22/10/2009	ARG 27	NM 64374 88037	Freshwater	100	-
28	22/10/2009	ARG 28	NM 64395 88156	Seawater	2	34.5

Highest results came from suspected septic discharges. These were all located around Morroch Point, south of Arisaig. One other freshwater sample contained an E. coli concentration of 800 cfu/100ml, and this came from a stream draining land grazed by cattle and discharging to the north of the village.

Table 3 Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (MPN/ 100g)
1	20/10/2009	ARGSF1	NM 64151 86850	Pacific oyster	330
2	20/10/2009	ARGSF2	NM 64119 86670	Pacific oyster	50
3	21/10/2009	ARGSF3	NM 63887 85317	Pacific oyster	70
4	21/10/2009	ARGSF4	NM 63863 85374	Pacific oyster	50

The oyster sample taken from the north end of the trestles at Sgeir Philip contained an *E. coli* concentration of 330 MPN/100g. The remaining three samples all had much lower E. coli concentrations.

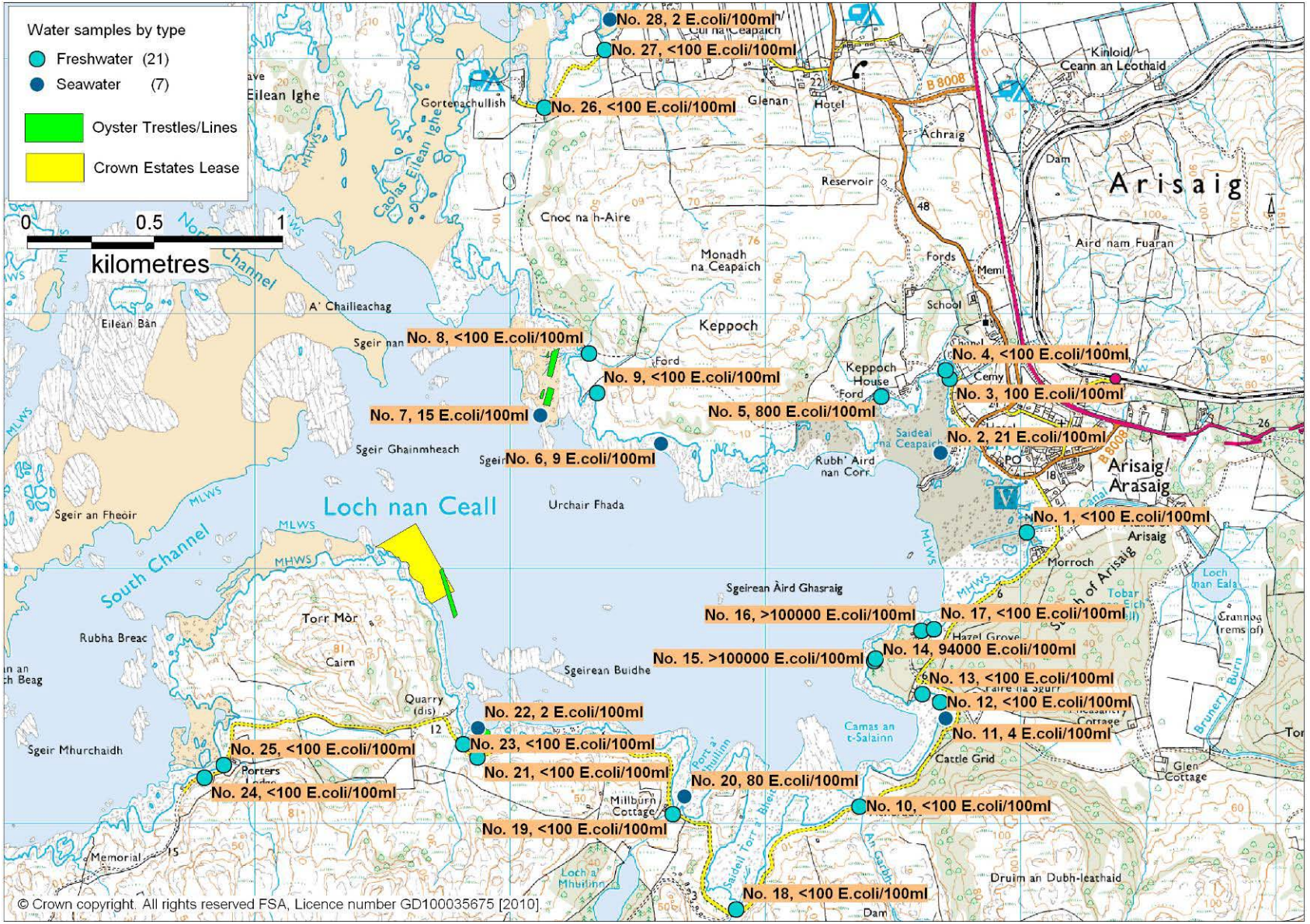


Figure 2 Water sample results map – Arisaig

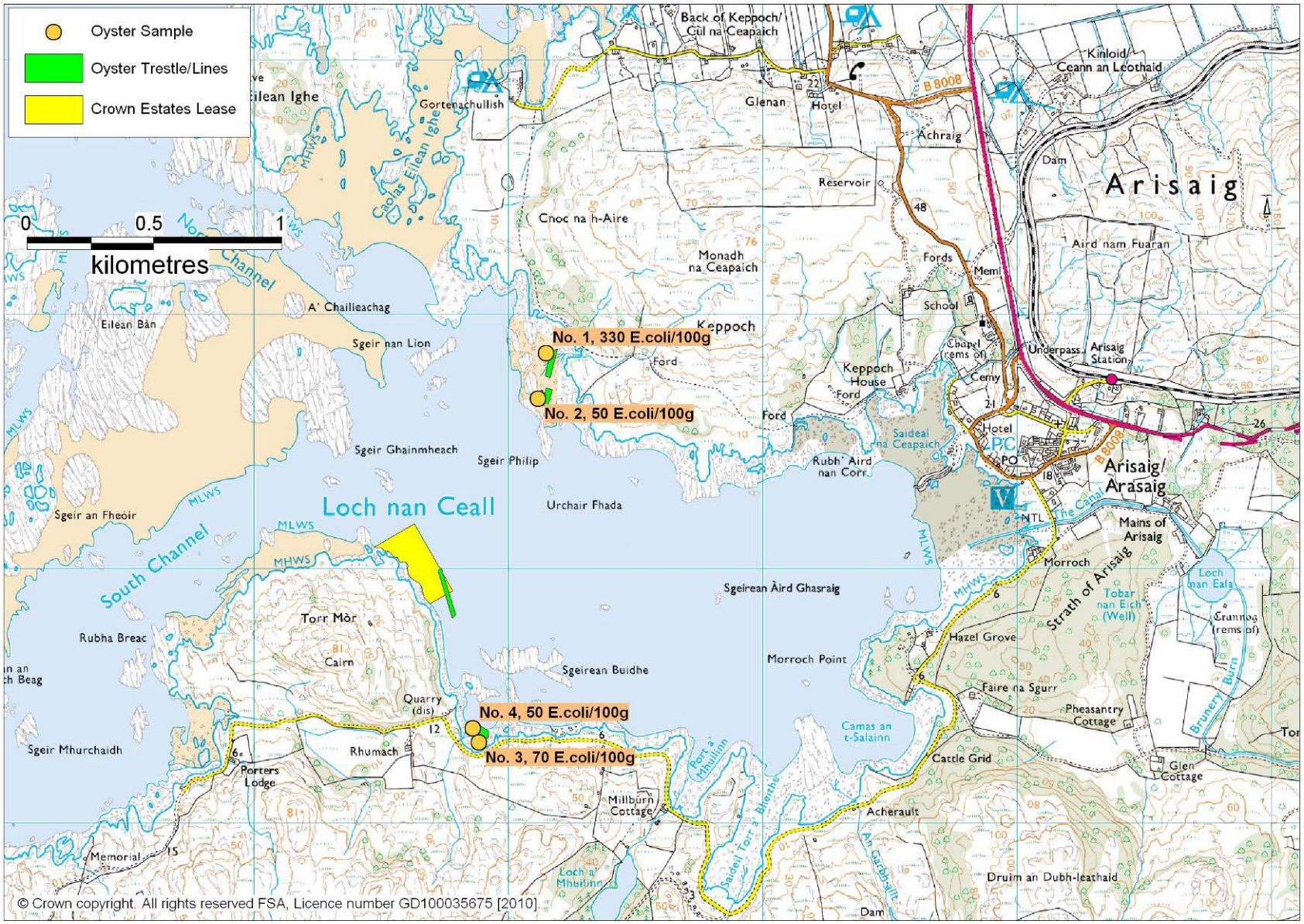


Figure 3 Shellfish sample results map - Arisaig

Photographs

Figure 4 Septic tank at Arisaig

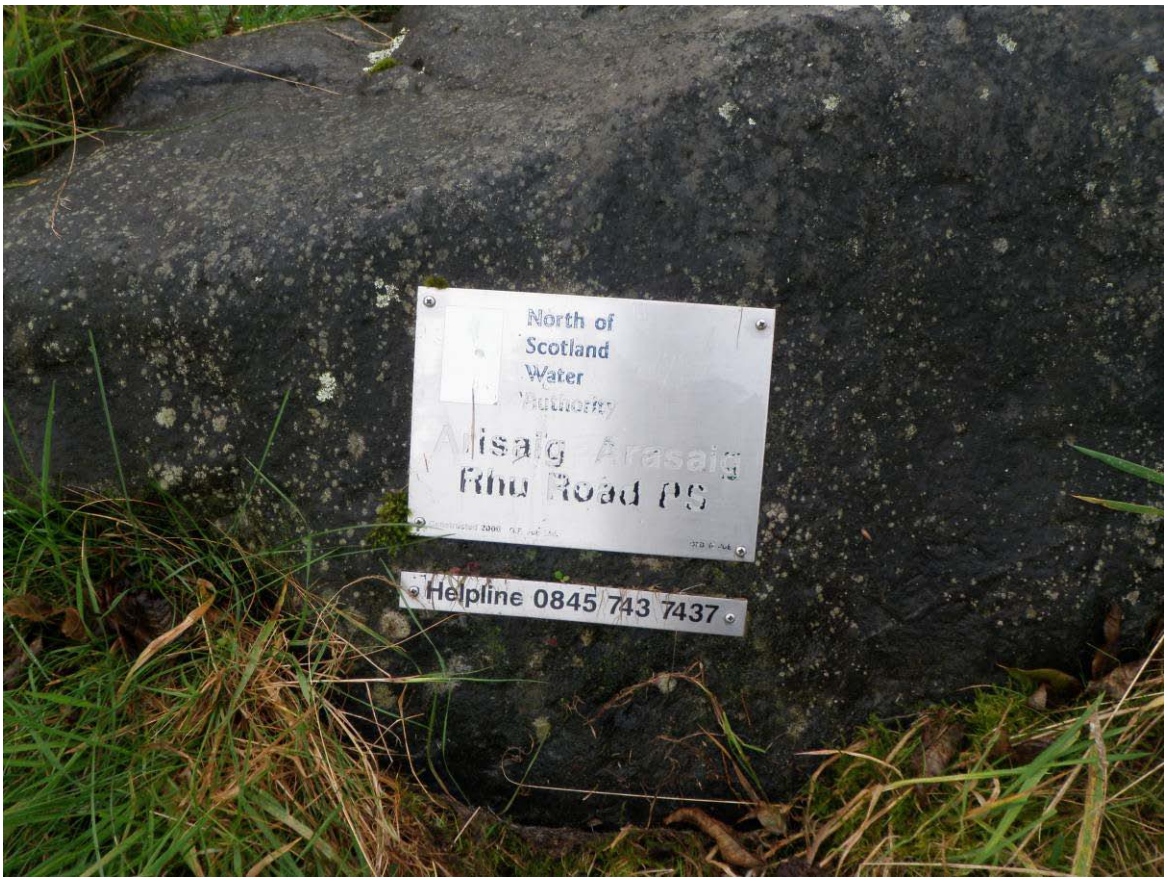


Figure 5 Rhu Road PS signage

Figure 6 Arisaig village

Figure 7. Edge of boatyard, with yachts moored in bay beyond

Figure 8 Overview of trestles near Sgeir Philip/North Channel

Figure 9 Trestles at Sgier Philip

Figure 10 Area of single trestles at Sgeir Philip

Figure 11 Collecting oyster samples

Figure 12 Stream with boggy area

Figure 13 The An Garbh-allt just above shoreline

Figure 14 Cows at cattle grid on road near Camas an t-Salainn

Figure 15 Discharge pipe on shore at Camas an t-Salainn

Figure 16. Septic tank with overflow pipe, Camas an t-Salainn

Figure 17 Small stream across rocky shore

Figure 18 Overview of SgeireanBuidhe oyster trestles

Figure 19 SgeireanBuidhe trestles, looking northeast toward shore

Figure 20 Stream crossing shoreline to west of SgeireanBuidhe trestles

Figure 21 Septic tank at boatyard

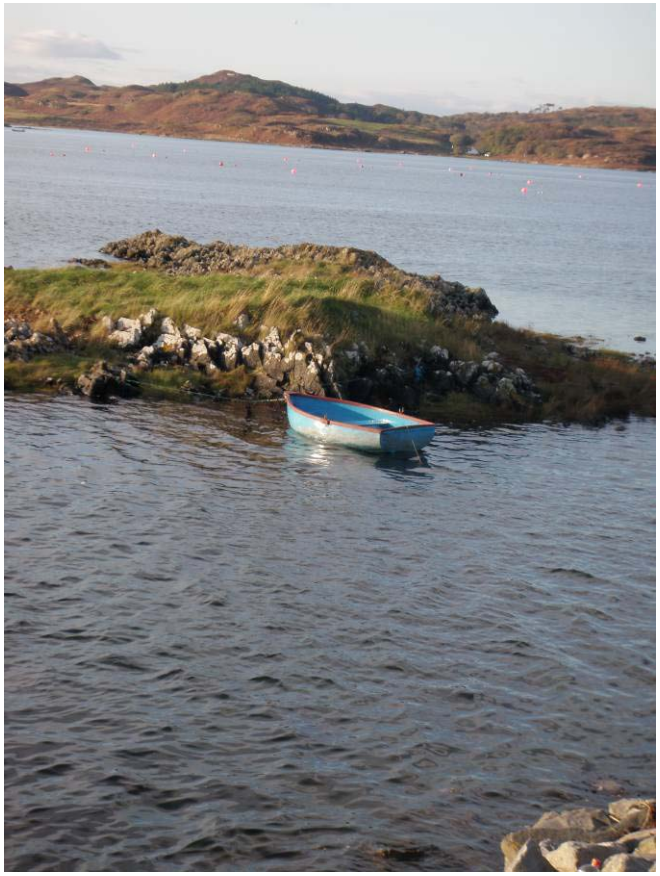


Figure 22 Moorings off Arisaig in background
Figure 23 Measuring stream near Porters Lodge
Figure 24 Stream near caravans at Back of Keppoch