Scottish Sanitary Survey Project

Sanitary Survey Report
Loch Scridain East and West
AB 314 and AB 315
June 2008

Final Report Distribution – Loch Scridain

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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 Scridain lies north of the Ross of Mull in Argyll & Bute in Southwestern Scotland. It is a west-facing loch with a length of 12km, maximum depth of 121m and it is open to prevailing winds. It contains one sill at the mouth of the loch.

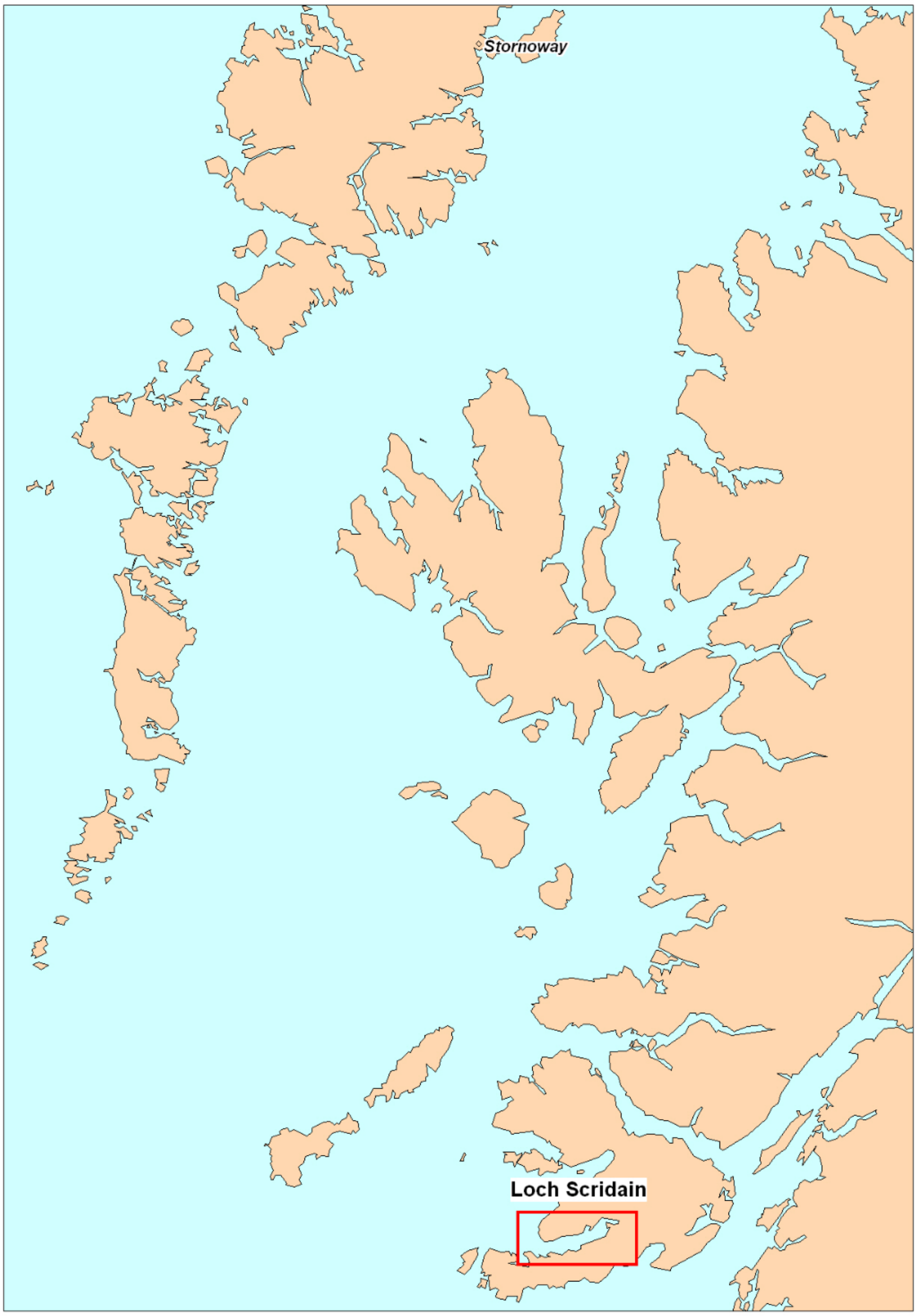


Figure 1.1 Location of Loch Scridain

This survey was triggered by the high score Loch Scridain East received in the risk matrix, primarily due to unexpected results. Loch Scridain West was included due to proximity.

2. Fishery

The fishery at Loch Scridain is comprised of two long line mussel (*Mytilus* sp.) farms as listed in Table 2.1 below:

Table 2.1 Loch Scridain shellfish farms

Site	SIN	Species
Loch Scridain East: Loch Scridain	AB314 05 408	Common mussels
Loch Scridain West: Knockan	AB315 05 308	Common mussels

There are two production areas for Loch Scridain. Loch Scridain East current production area is bounded by lines drawn between NM 4460 2700 to NM 4460 2419 and between NM 5200 2969 to NM 5200 2663. Loch Scridain West current production area is bounded by lines drawn between NM 4060 2697 to NM 4060 2368 and between NM 4460 2700 to NM 4460 2419.

The RMP for the Loch Scridain East: Loch Scridain production area is currently stated at NM 455 250.

Loch Scridain East: Loch Scridain is a large mussel farm, where mussels are grown on ropes suspended from float lines. The site is 3 float lines long, and 6 to 8 float lines wide. A variety of sizes were present from empty ropes to harvestable mussels at the time of the shoreline survey. The growing ropes were approximately 8m long.

Loch Scridain West: Knockan consists of a single raft with an estimated size of 12mx12m from which growing ropes are suspended. The ropes examined during the shoreline survey were approximately 4m long, and had mussels of different sizes attached, including some that were larger than the typical harvesting size. The RMP for the production area is currently stated at NM 408 239. The raft is located approximately 90m north of the currently identified grid reference for the RMP at NM 408 239.

Figure 2.1 shows the relative positions of the mussel farms, Food Standard Agency Scotland designated Production Area, SEPA designated growing waters, and the seabed lease areas.

In addition to these (FSAS listed) sites, another two mussel culture sites were seen within the Loch Scridain East production area during the shoreline survey. The first coincided approximately with the Crown Estates lease at the north east end of the loch, and consisted only of a single row of floats, which were too widely spaced to support mussel ropes beneath. It is reported that this site is currently in a fallow state. The second was located near the north shore, approximately opposite to the Loch Scridain East: Loch Scridain site. This consisted of 7 lines of floats, some of which appeared to be supporting fairly heavy growth. Both these sites are under the same ownership as the Loch Scridain East: Loch Scridain site. Positions of these two unnamed sites are approximate as they were estimated from the shore.

It is assumed that the harvester would be keen for the site which appeared to support stock to remain classified, as it may be scheduled for harvest soon.

Subsequent to the distribution of the draft sanitary survey report, the sampling officer reported that the mussel raft at Loch Scridain West had shifted during a storm and was now located at NM 4081 2398, approximately 40 m away from where it had originally been located. Due to a broken mooring line, this raft was observed to shift 30-40 m, depending on the wind direction and state of tide.

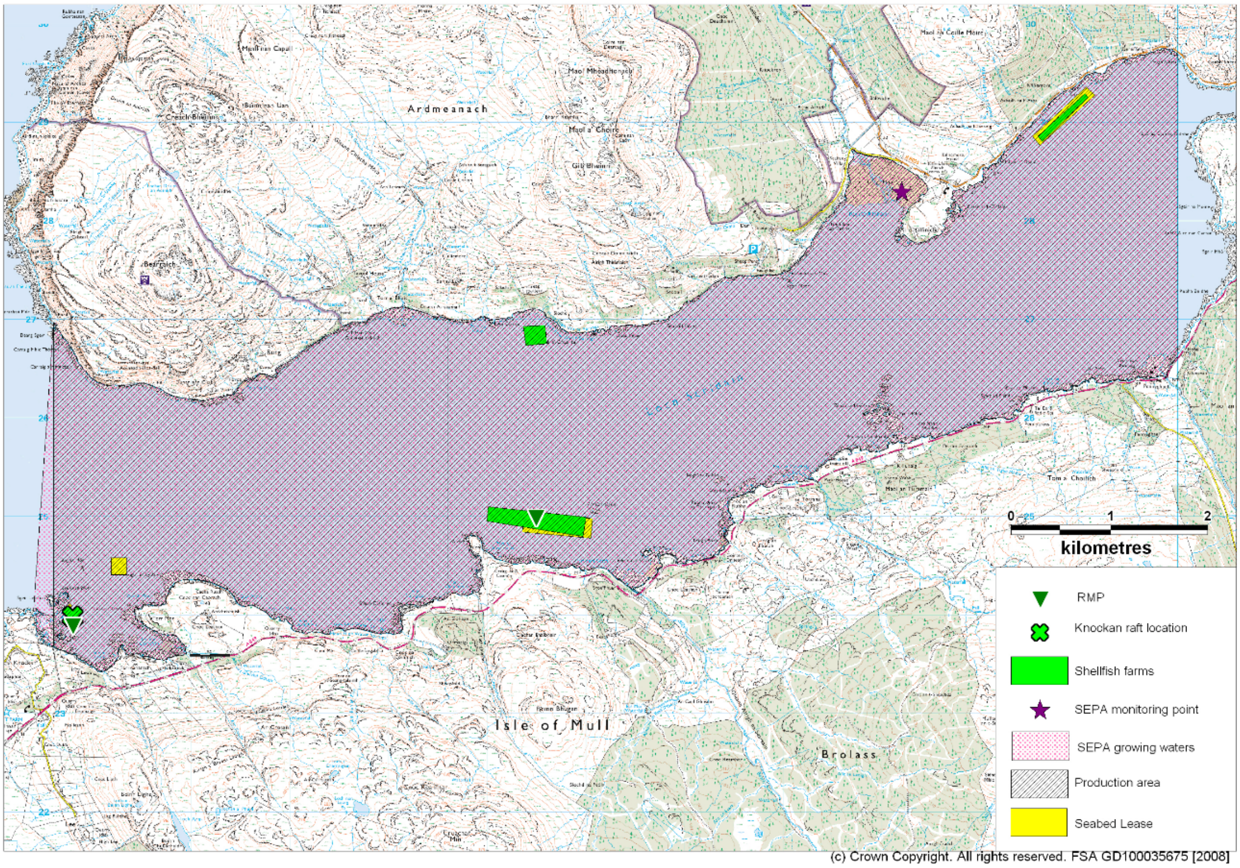


Figure 2.1 Map of Loch Scridain Fishery

3. Human population

The figure below shows information obtained from the General Register Office for Scotland on the population within the census output in the vicinity of Loch Scridain.

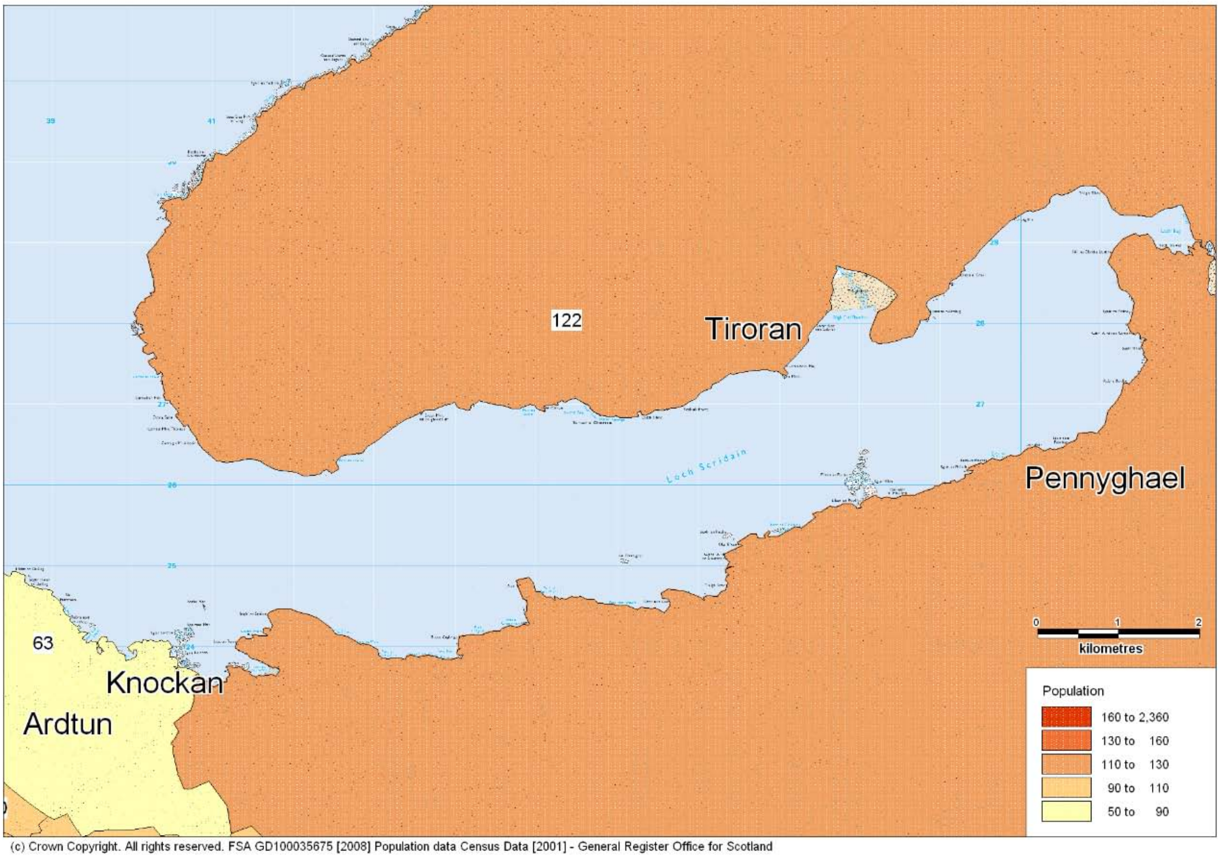


Figure 3.1 Population distribution map of Loch Scridain

The population for the two census output areas bordering immediately on Loch Scridain are:

60QD000583	63
60QD000584	122

On the northern side of the loch there is only one small settlement called Tiroran. On the southern side of the loch are the settlements of Ardtun, Knockan and Pennyghael. Most of the population is concentrated towards the far southeastern and far sothwestern ends of the loch so any associated faecal pollution from human sources will be concentrated in these areas. Overall, the loch is large, and the population on its shores is sparse.

4. Sewage Discharges

There are no Scottish Water public wastewater discharges in the vicinity of Loch Scridain.

A number of discharge consents were held by SEPA for the area of Loch Scridain. These are listed in Table 4.1 and mapped in figure 4.1.

Table 4.1 SEPA discharge consents

Ref No.	NGR of discharge	Discharge Type	PE
CAR/R/1013638	NM 4870029340	Sewage (Private) Primary	7
CAR/R/1009214	NM 4866228523	Sewage (Private) Primary	15
CAR/R/1018620	NM 4798027810	Sewage (Private) Primary	5
CAR/R/1017505	NM 5188626415	Sewage (Private) Primary	11
CAR/R/1018563	NM 3919 2395	Sewage (Private) Primary	5
CAR/R/1018403	NM 4074021780	Sewage (Private) Primary	10
CAR/L/1011374	NM 4042721148	Unknown – Information requested	-

Observations of additional discharges, including septic tanks and outfall pipes were also observed during the shoreline survey. These were not all confirmed as active or discharging during the survey, however their locations have been included in the mapped discharges in Figure 4.1 and listed in Table 4.2 below. Further details can be found in the shoreline survey report in the appendix.

Table 4.2 Additional discharges observed during the shoreline survey

No	Date	NGR	Description of potential sewage discharge
1	04-Sep-07	NM 38239 21818	Septic tank
2	04-Sep-07	NM 38193 22072	Sewer pipes discharging at shore
3	05-Sep-07	NM 51840 26401	Septic tank and pipe discharging at river mouth
4	05-Sep-07	NM 52069 26677	Septic tank with overflow to beach
5	06-Sep-07	NM 52051 29651	Inspection cover
6	06-Sep-07	NM 51552 29655	Septic tank with overflow to beach (not flowing)

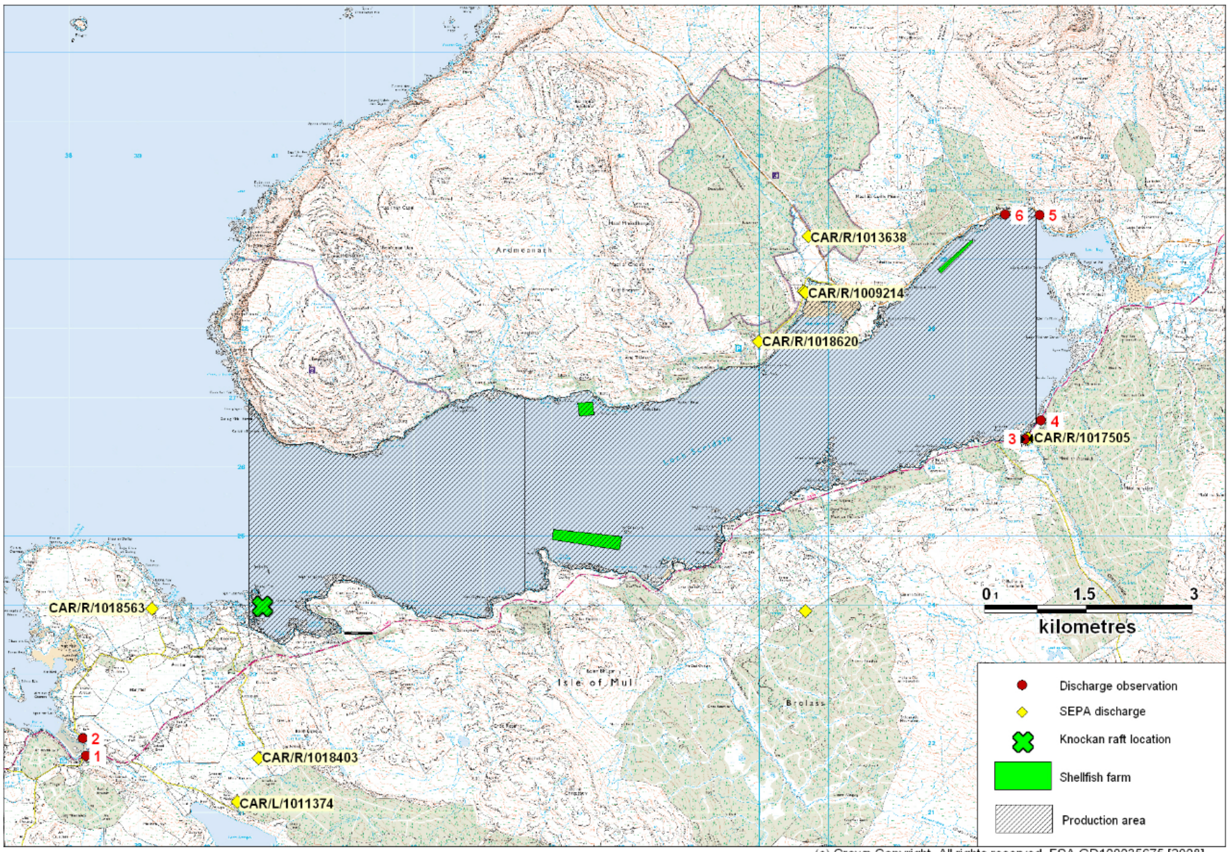


Figure 4.1 Map of Sewage discharges at Loch Scridain

The majority of known sewage input is concentrated towards the eastern end of the loch where there are several private septic tanks. It is expected that these would be a less significant source of contamination due to the large distance between the discharge location and the active shellfish farms, but some, particularly observations 5 and 6 are likely to affect the fallow site at the north east of the loch.

5. Geology and soils

Component soils and their associations were identified using uncoloured soil maps (scale 1:50000) obtained from the Macaulay Institute. The relevant soil associations and component soils were then researched to establish basic characteristics. 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 (see the glossary at the end of this section).

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.

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% and can be classified as freely draining soils.

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. In addition, they also have a very high surface % runoff of between 48.4 – 60%, confirming that they are poorly draining.

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 the regions mapped have an average surface % runoff of 44.3%, so it is likely that in this case they would be poorly draining.

Maps were produced using these seven soil type groups and whether they are characteristically freely or poorly draining (for an example see Figure 5.1). The map of component soils and their associated drainage classes for the area around Loch Scridain can be found in Figure 5.1.

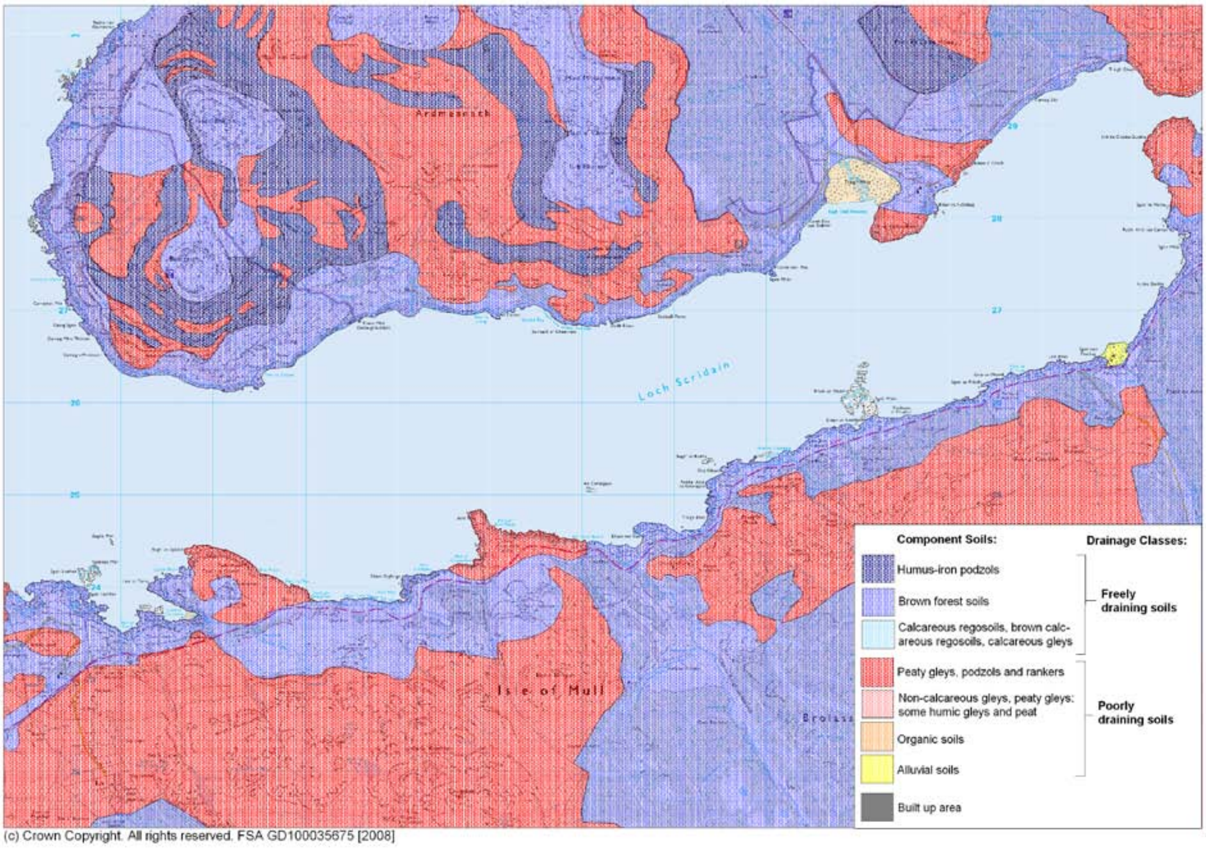


Figure 5.1 Map of component soils and drainage classes for Loch Scridain

There are four main types of component soils visible in the area of Loch Scridain. The most dominant is brown forest soils (freely draining) and this covers much of the coastline of Loch Scridain and also a large inland area to the south and further patches inland to the north. The second dominant component soil type is composed of peaty gleys, podzols and rankers (poorly draining). This soil type is located on some parts of the southern coastline, however it is mainly situated further inland in large patches to the south and more fragmented patches to the north. The third component soil type is humus-iron podzols (freely draining) and this is only visible on the northern side of Loch Scridain, especially towards the northwest opening of the loch. The final component soil type is alluvial soils (poorly draining) and only occurs in one small area on the southeastern coastline.

Overall, the potential for runoff contaminated with *E. coli* from animal waste based on the soil types present is relatively low. However, as the coastal bands of freely draining soils are neighboured with substantial areas of poorly draining soils this may increase the risk of contamination in times of high rainfall.

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.

6. Land cover

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

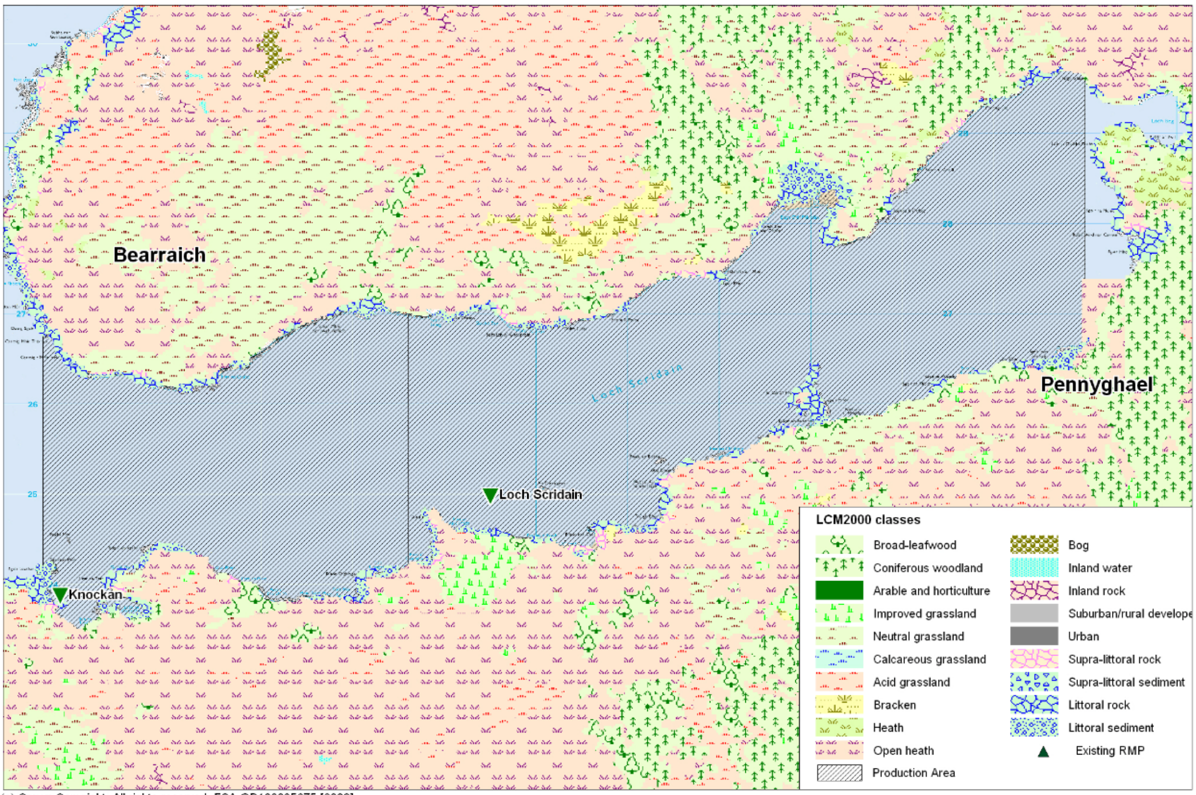


Figure 6.1 LCM2000 class data map for Loch Scridain

The land cover on the south coast of Loch Scridain is dominated by open heath with some improved grassland and areas of broad-leaf and coniferous woodland. There are also some areas of acid grassland scattered amongst the open heathland. The land cover on the northern coast of Loch Scridain is more mixed with patches of neutral grassland, open heath, broad-leaf woodland, coniferous woodland, acid grassland and bracken. Along much of the coastline of Loch Scridain are areas of littoral sediment and littoral rock.

The faecal coliform contribution would be expected to be highest from developed areas (approx 1.2 – 2.8×10^{9} cfu km^{-2} hr^{-1}), with intermediate contributions from the improved grassland (approximately 8.3×10^{8} cfu km^{-2} hr^{-1}) and lowest from the other land cover types (approximately 2.5×10^{8} cfu km^{-2} hr^{-1}) (Kay *et al*. 2008). The contributions from all land cover types would be expected to increase significantly after marked rainfall events, this being expected to be highest, at more than 100-fold, for the improved grassland.

As there are no developed areas, and little improved grassland shown on Figure 6.1, the majority of land cover types fall into the category contributing the lowest levels of faecal coliforms.

7. Farm Animals

Regulation (EC) No. 854/2004 requires the competent authority to:

(a) make an inventory of the sources of pollution of human or animal origin likely to be a source of contamination for the production area;
(b) examine the quantities of organic pollutants which are released during the different periods of the year, according to the seasonal variations of both human and animal populations in the catchment area, rainfall readings, waste-water treatment, etc.

With regard to potential sources of pollution of animal origin, agricultural census data to parish level was requested from the Scottish Government. The request was declined on the grounds of confidentiality because the parishes in most cases contained only a small number of farms making it possible to determine specific data for individual farms. The only significant source of information was therefore the shoreline survey (see Appendix), which only relates to the time of the site visit on 4^{th} - 6^{th} September 2007.

The shoreline survey identified that livestock, primarily sheep but some cattle, were grazed widely around the loch. The highest concentration was seen at the southeast corner of the loch, on improved pastures around Rossal Farm. Significant concentrations were also noted in northeast, southeast and the southwest corners (see Figure 7.1). The geographical spread of contamination at the shores of the loch is likely concentrated to these regions and therefore this factor should be taken into account when identifying the location of a representative monitoring point (RMP). Based on proximity of the sites to aggregations of livestock as seen on the shoreline survey, the fallow site at the north east end of the loch would be impacted most heavily. The Knockan site was also close to an aggregation of livestock.

Local information was not available for the seasonal numbers of livestock for the land surrounding Loch Scridain, although it is likely that numbers of livestock increase significantly following lambing in the spring, and decrease in the autumn when the lambs are sent to market.

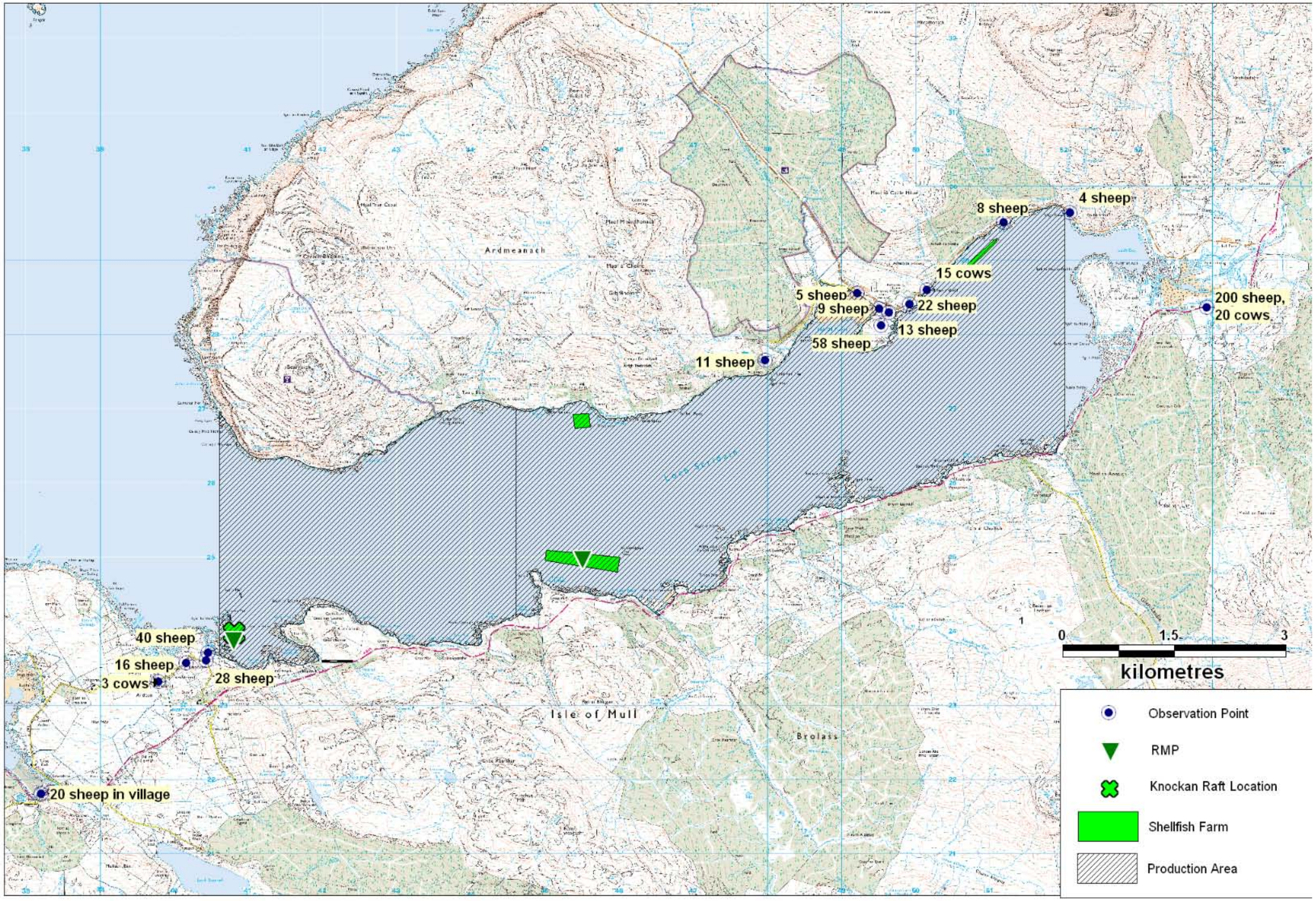


Figure 7.1 Map of livestock observations at Loch Scridain

8. Wildlife

8.1 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*). Scotland hosts significant populations of both species.

The amount 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 x 10^4 CFU (colony forming units) *E. coli* per gram dry weight of faeces (Lisle *et al*, 2004).

Common seals 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.

A survey conducted by the Sea Mammal Research Unit in 2000, indicated that there was an estimated 1616 common seals on the Isle of Mull. It must be noted that these figures are likely to have changed slightly as a result of the year (2000) that the data was collected. Due to not being able to specify the exact location of the haul out sites the impact that they could potentially have on the shellfish farm is unpredictable. A few seals were seen during the course of the shoreline survey in the rocky bay in which the Loch Scridain West: Knockan site is located.

Adult Grey seals weigh 150-220 kg and adult common seals 50-170 kg. 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 110 kg, that would equate to 6.6 kg consumed per day and probably very nearly that defecated.

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).

Seals will forage widely for food and it is likely that seals will feed near the mussel farms at some point in time. The population is relatively small in relation to the size of the area concerned and is highly mobile therefore it is likely that any impact will be limited in time and area and unpredictable.

8.2 Cetaceans

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

Table 8.1 Cetacean sightings in 2007 – Western Scotland.

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

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

Within the Loch Scridain it is likely that cetaceans may be present from time to time, especially the smaller species. Their presence, however, is likely to be fleeting and unpredictable and so will not be taken into account with regard to establishing sampling plans for the Loch Scridain production areas.

8.3 Seabirds

A number of seabird species are known to breed in Argyll & Bute and the most significant of these are described in table 8.2.

Table 8.2 Breeding seabirds of Argyll & Bute

Common name	Species	Population	Common name	Species	Population
European Shag	*Phalacrocorax aristotelis*	3341	Great Cormorant	*Phalacrocorax carbo*	231*
Black-headed Gull	*Larus ridibundus*	586	Common Gull	*Larus canus*	2683
Lesser Black-backed Gull	*Larus fuscus*	3235	Herring Gull	*Larus argentatus*	15370
Great Black-backed Gull	*Larus marinus*	1736	Black-legged Kittiwake	*Rissa tridactyla*	8976
Common Tern	*Sterna hirundo*	1362	Arctic Tern	*Sterna paradisaea*	1823
Common Guillemot	*Uria aalge*	42697	Black Guillemot	*Cepphus grille*	3046
Razorbill	*Alca torda*	9056	Atlantic Puffin	*Fratercula arctica*	2597*

*Population number based on Apparently Occupied Sites, Territories, Nests or Burrows. These may equate to more than one adult.

Distribution of nesting sites near the harvesting areas is not known. Though nesting occurs in early summer, these birds are likely to be present in the area throughout the year. Impact to the fisheries is likely to be very localised where birds rest on floats.

Wading birds frequent the intertidal areas of the loch, and waterfowl (ducks and geese) are present in Argyll & Bute at various times of the year, though information on numbers and specific locations was not available at the time this report was written.

Overall, some very minor impacts from birds using the intertidal areas, resting on floats, or via land runoff may be expected, but these will not materially affect sampling plans.

8.4 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. Part of the shoreline of Loch Scridain is wooded. While no population data were available for this specific area, it can be presumed that they host populations of deer. The DCS report a count of 1011 red deer and 1 roe deer for the whole of Mull, the total area of which is approximately 950 km^2. Therefore the overall density of about 1 deer per km^2 is low relative to that of livestock.

Deer, like cattle and other ruminants, shed *E. coli*, *Salmonella* and other potentially pathogenic bacteria via their faeces and it is likely that some of the indicator organisms detected in the streams feeding into Loch Scridain will be of deer origin, although this will not materially affect the sampling plans.

8.5 Other

The European Otter (*Lutra lutra*) is present around Scotland with some areas hosting populations of international significance. Coastal otters, such as those found in Loch Scridain, 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 will primarily forage within the 10 m depth contour. (Paul Harvey, Shetland Sea Mammal Group, personal communication).

Otters leave faeces (also known as spraint) along the shoreline or along streams. Two otters were seen during the course of the shoreline survey. Given their low population density their impacts on the shellfishery will be very minor, and will not materially affect sampling plans.

8.6 Summary

Wildlife impacts to the fisheries at Loch Scridain are likely to be localised and unpredictable. As a consequence, they will not materially affect the sampling plans.

9. Meteorological data

The nearest weather station is located at Mull: Gruline, approximately 13 km to the north east of the production area. Rainfall data was supplied for the period 1/1/2003 to 31/10/2006 (total daily rainfall in mm). For this period of 1400 days, total daily rainfall was not recorded on 61 days. Wind data was not recorded at this station. It is likely that rainfall experienced at Mull: Gruline is very similar to that experienced at the production area due to their close proximity.

The nearest major weather station is located at Tiree, approximately 45 km to the west of the production area. Rainfall data was recorded on all but 11 days from 1/1/2003 to 31/12/2006. Wind direction was recorded at 3 hourly intervals for the majority of the period 1/1/2003 to 31/12/2006. It is likely that the rainfall and wind patterns at Tiree are broadly similar to those at Loch Scridain, but are liable to differ on any given day. Local topography may also affect wind strength and direction.

This section aims to describe the local rain and wind patterns and how they may affect the bacterial quality of shellfish within the Loch Scridain production areas.

9.1 Rainfall

High rainfall and storm events are commonly associated with increased faecal contamination of coastal waters through surface water run-off from land where livestock or other animals are present, and through sewer and wastewater treatment plant overflows (e.g. Mallin et al, 2001; Lee & Morgan, 2003).

9.1.1 Rainfall at Mull: Gruline

Due to the number of days rainfall data which were not recorded, it is not appropriate to present monthly or annual totals. Instead, box and whisker plots summarising the distribution of individual daily rainfall values by month and by year are presented in Figures 9.1 and 9.2. 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 *.

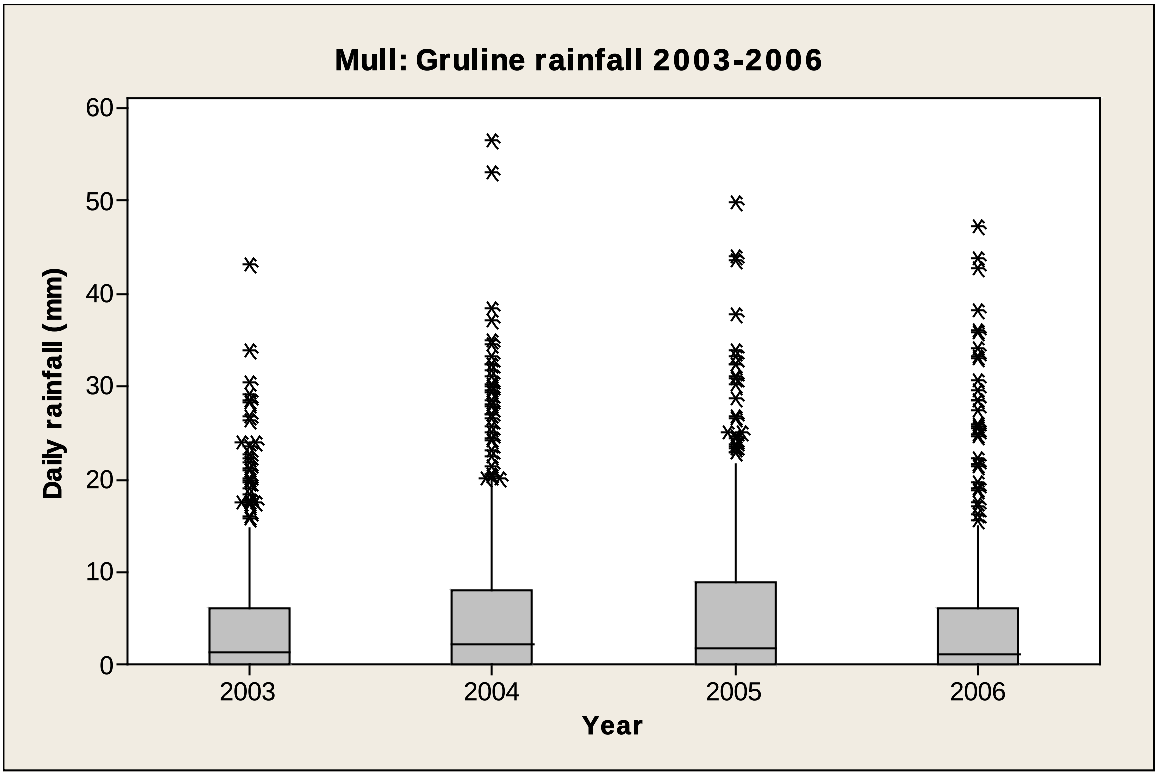


Figure 9.1 Boxplot of daily rainfall at Mull: Gruline by year (September 2004 and October 2006)

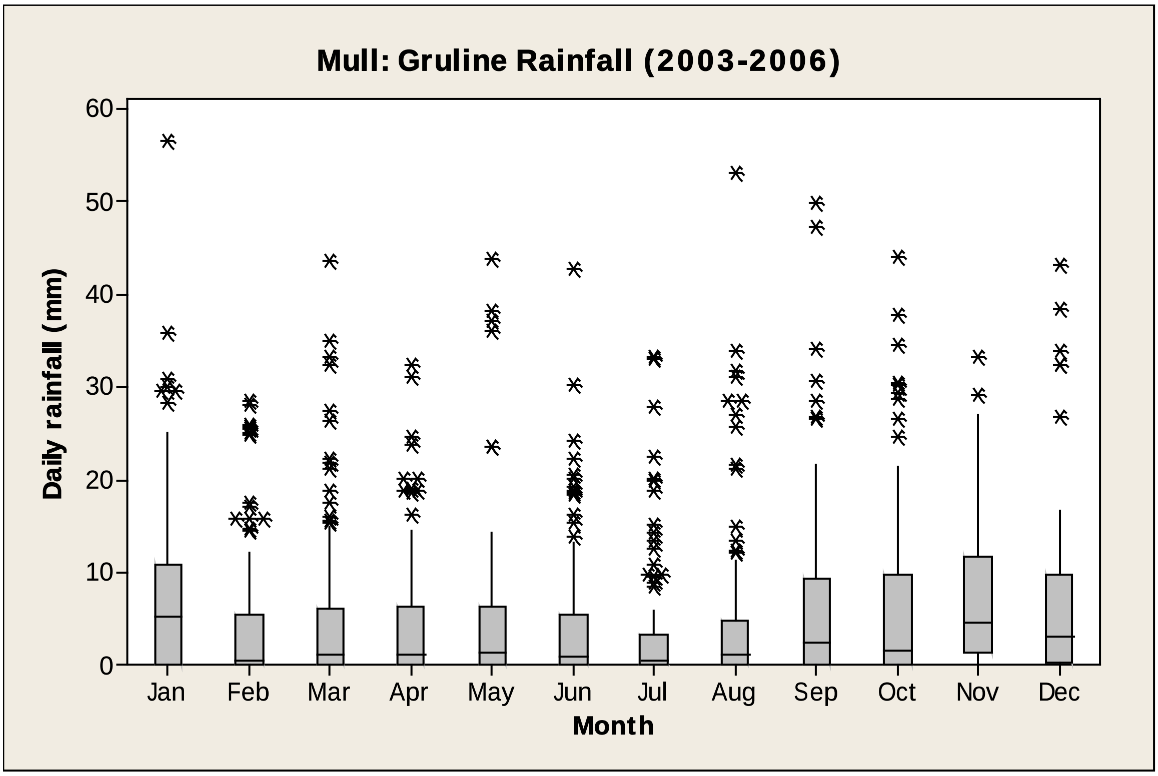


Figure 9.2 Boxplot of daily rainfall at Mull: Gruline by month (September 2004 and October 2006)

Higher median daily rainfall was recorded in 2004 and 2005. Higher median daily rainfall was recorded in September, October, November, December and January.

9.1.2 Rainfall at Tiree

As the rainfall records from Tiree are more complete, total annual rainfall and mean monthly rainfall can be calculated, and are presented in Figures 9.3 and 9.4. Boxplots of daily rainfall values by year and by month are presented in Figures 9.5 and 9.6 to allow their comparison with the pattern of rainfall at Mull: Gruline.

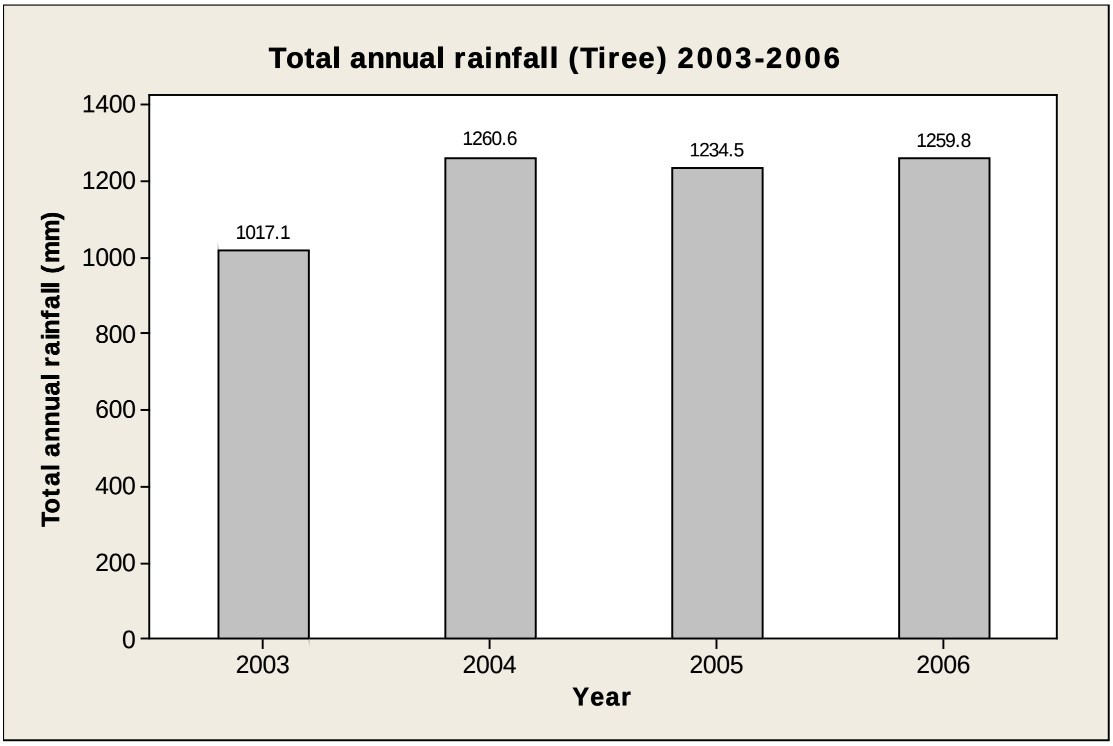


Figure 9.3 Total annual rainfall at Tiree 2003-2006 (no records for 11 days in 2006).

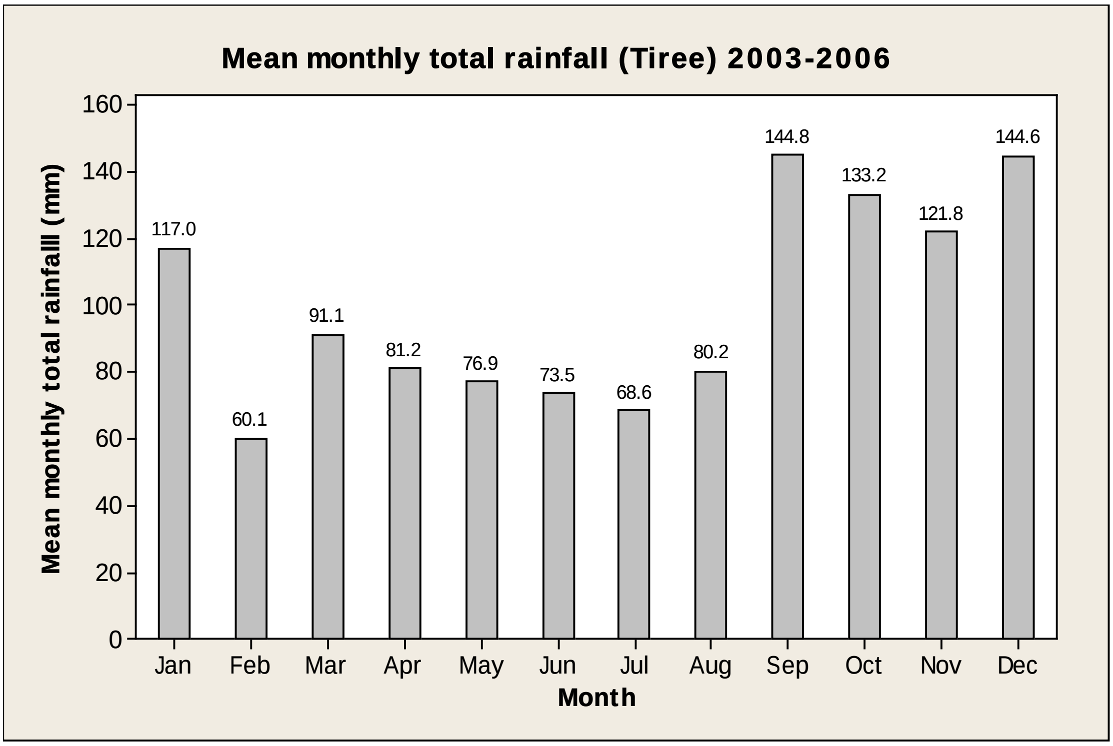


Figure 9.4 Mean total monthly rainfall at Tiree 2003-2006 (no records for 6 days in August 2006 and 5 days in October 2006).

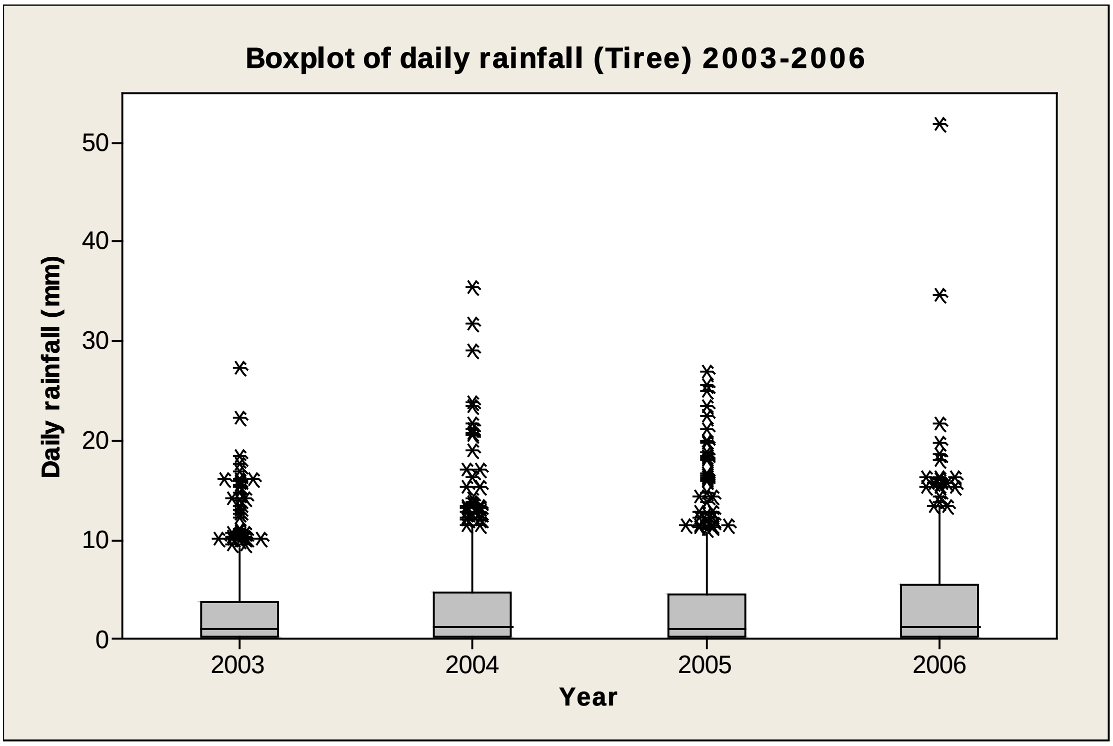


Figure 9.5 Boxplot of daily rainfall at Tiree by year

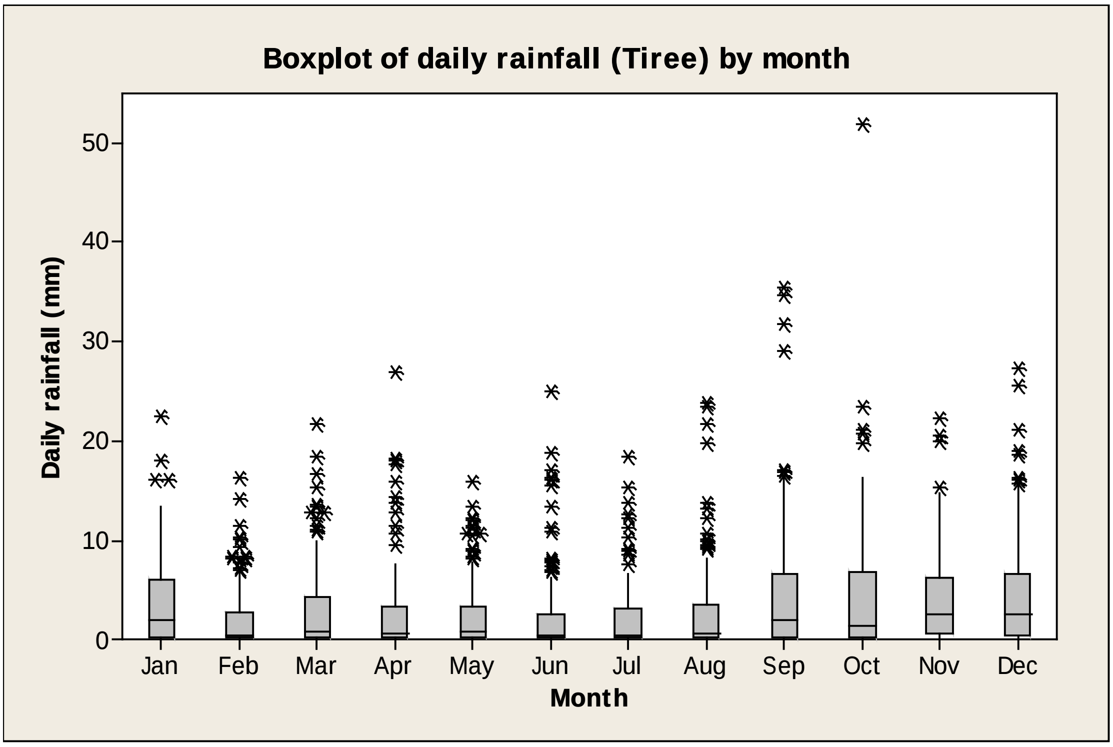


Figure 9.6 Boxplot of daily rainfall at Tiree by month

2003 was drier than 2004-2006, which had similar total annual rainfall. The wettest months were September, October, November, December and January. For the period considered here (2003-2006), only 13.3% of days experienced no rainfall. 50.7% of days experienced rainfall of 1mm or less.

A comparison of Tiree rainfall data with Scotland average rainfall data for the period of 1970-2000 is presented in Table 9.1 (Data from Met office website © Crown copyright). This indicates that rainfall in Tiree was lower than the average for the whole of Scotland for every month of the year, but there were fewer dry days in Tiree during the autumn and winter.

Table 9.1 - Comparison of Tiree mean monthly rainfall with Scottish average 1970-2000.

Month	Scotland rainfall (mm)	Tiree rainfall (mm)	Scotland - days of rainfall >= 1mm	Tiree - days of rainfall >= 1mm
Jan	170.5	142.5	18.6	20.1
Feb	123.4	98.2	14.8	15.8
Mar	138.5	104.5	17.3	18.1
Apr	86.2	67.1	13	11.6
May	79	54.1	12.2	10.8
Jun	85.1	61.5	12.7	11.2
Jul	92.1	77.5	13.3	13.6
Aug	107.4	98.7	14.1	14.0
Sep	139.7	118.6	15.9	16.5
Oct	162.6	142.7	17.7	18.8
Nov	165.9	136.6	17.9	19.7
Dec	169.6	134.5	18.2	20.4
Whole year	1520.1	1236.4	185.8	190.6

It can therefore be expected that levels of rainfall-dependent faecal contamination entering the production area from these sources will be higher during the autumn and winter months. It is possible that faecal matter can build up on pastures during the drier summer months when stock levels are at their highest, leading to more significant faecal contamination of runoff at the onset of the wetter weather in the autumn.

9.2 Wind

Wind data collected at the Tiree weather station is summarised by season and presented in figures 9.7 to 9.11.

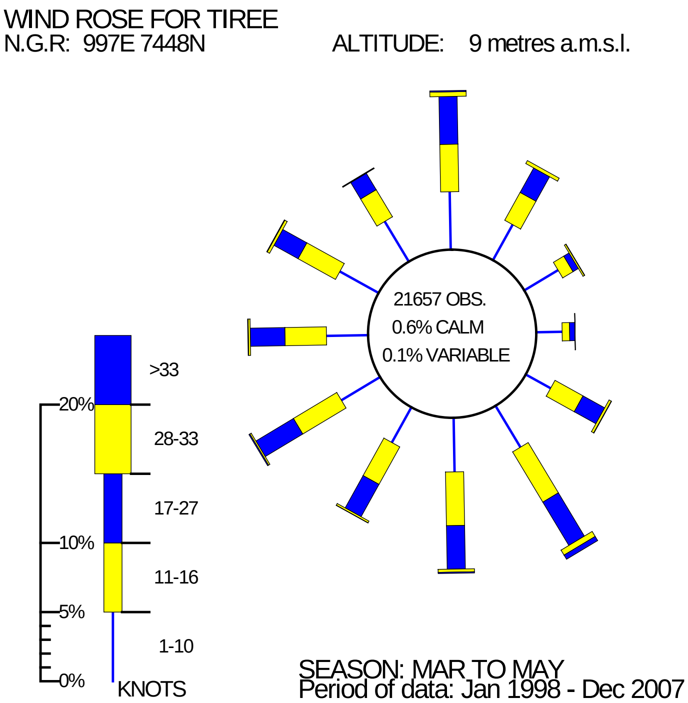


Figure 9.7 Wind rose for Tiree (March to May)

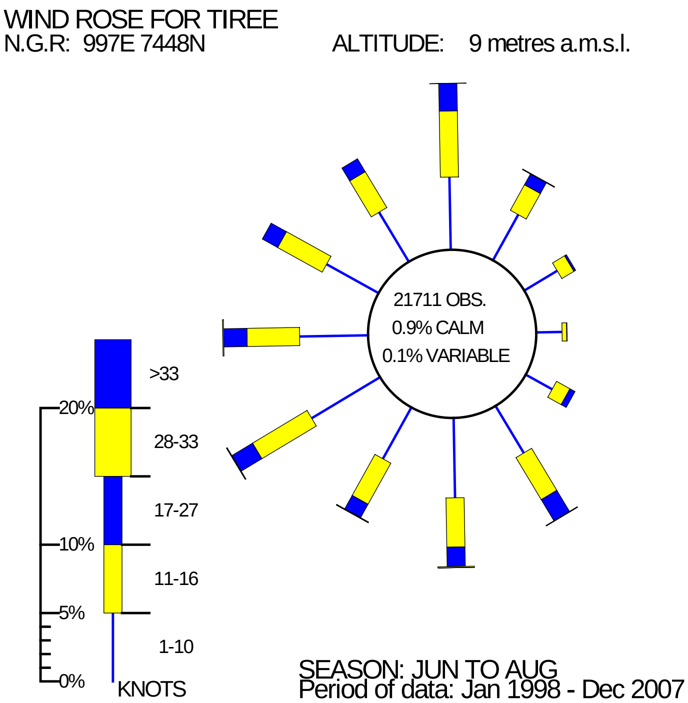


Figure 9.8 Wind rose for Tiree (June to August)

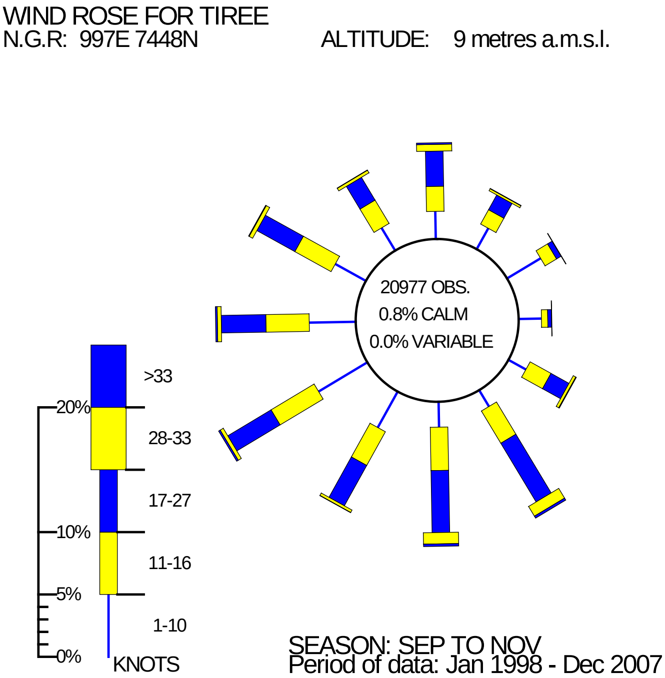


Figure 9.9 Wind rose for Tiree (September to November)

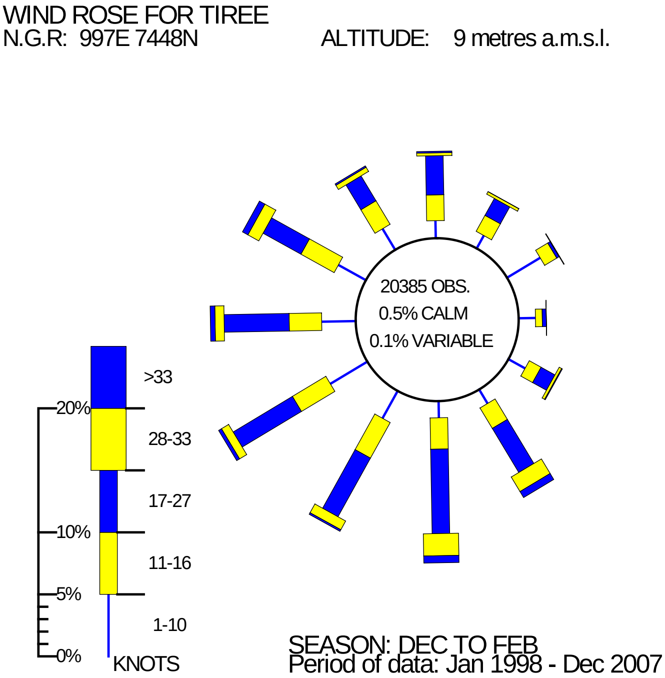


Figure 9.10 Wind rose for Tiree (December to February)

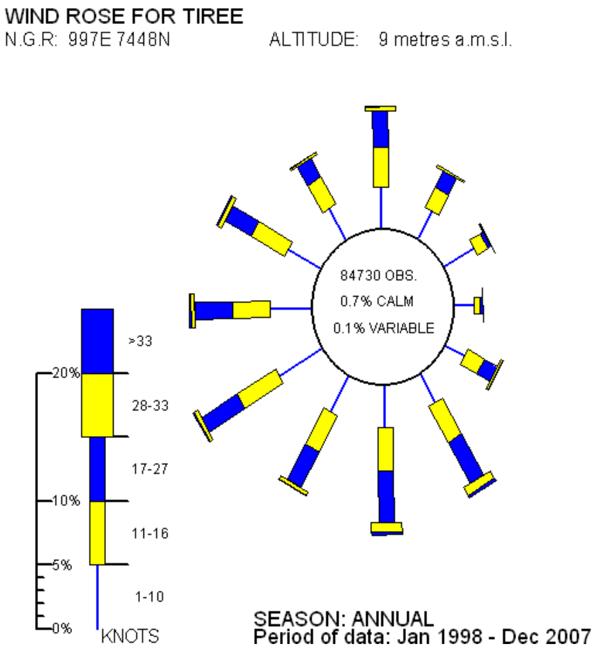


Figure 9.11 Wind rose for Tiree (All year)

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

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. 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.

Loch Scridain is a large sea loch, approximately 3 km wide and 12 km long which faces west to the Atlantic Ocean. The loch is surrounded by hills, rising to over 400 m in places, which will provide some shelter from northerly, southerly and easterly winds, and tend to funnel westerly winds up the length of the loch. A westerly gale is therefore likely to significantly change patterns of water circulation within the loch, driving a surface current from west to east.

10. Current and historical classification status

The survey area covers two adjoining production areas, Loch Scridain East (AB314) and Loch Scridain West (AB315). The current boundaries were created in 2005, when a larger production area covering both the current areas was split. The classification histories are presented in Tables 10.1 and 10.2. A map of the current production areas is presented in Figure 10.1. Figure 10.2 presents a larger scale view of part of the Loch Scridain West production area.

Table 10.1 Classification history, Loch Scridain East (AB314)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	A	A	A	A	A	A	B	B	B	A	A	A
2002	A	A	A	A	A	A	A	A	A	A	A	A
2003	A	A	A	A	A	A	A	A	B	A	A	A
2004	A	A	A	A	A	A	A	A	A	A	A	A
2005	A	A	B	B	B	B	B	B	B	A	A	A
2006	A	A	A	A	A	A	A	A	A	A	A	A
2007	A	A	A	B	B	B	B	B	B	B	B	B

Table 10.2 Classification history, Loch Scridain West (AB315)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	A	A	A	A	A	A	B	B	B	A	A	A
2002	A	A	A	A	A	A	A	A	A	A	A	A
2003	A	A	A	A	A	A	A	A	B	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	B	B	A	A
2006	A	A	A	A	A	A	A	A	A	A	A	A
2007	A	A	A	A	A	A	B	B	B	B	B	B

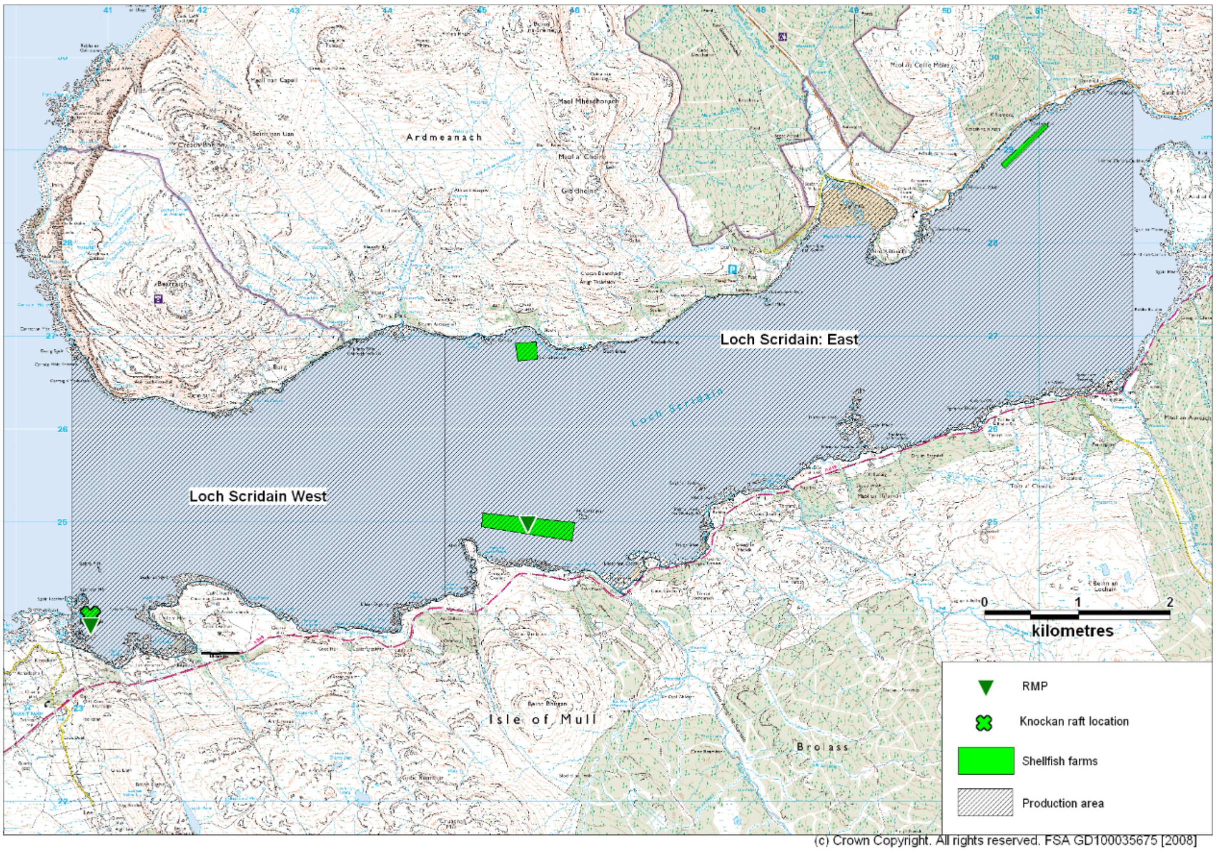


Figure 10.1 Map of loch Scridain production areas

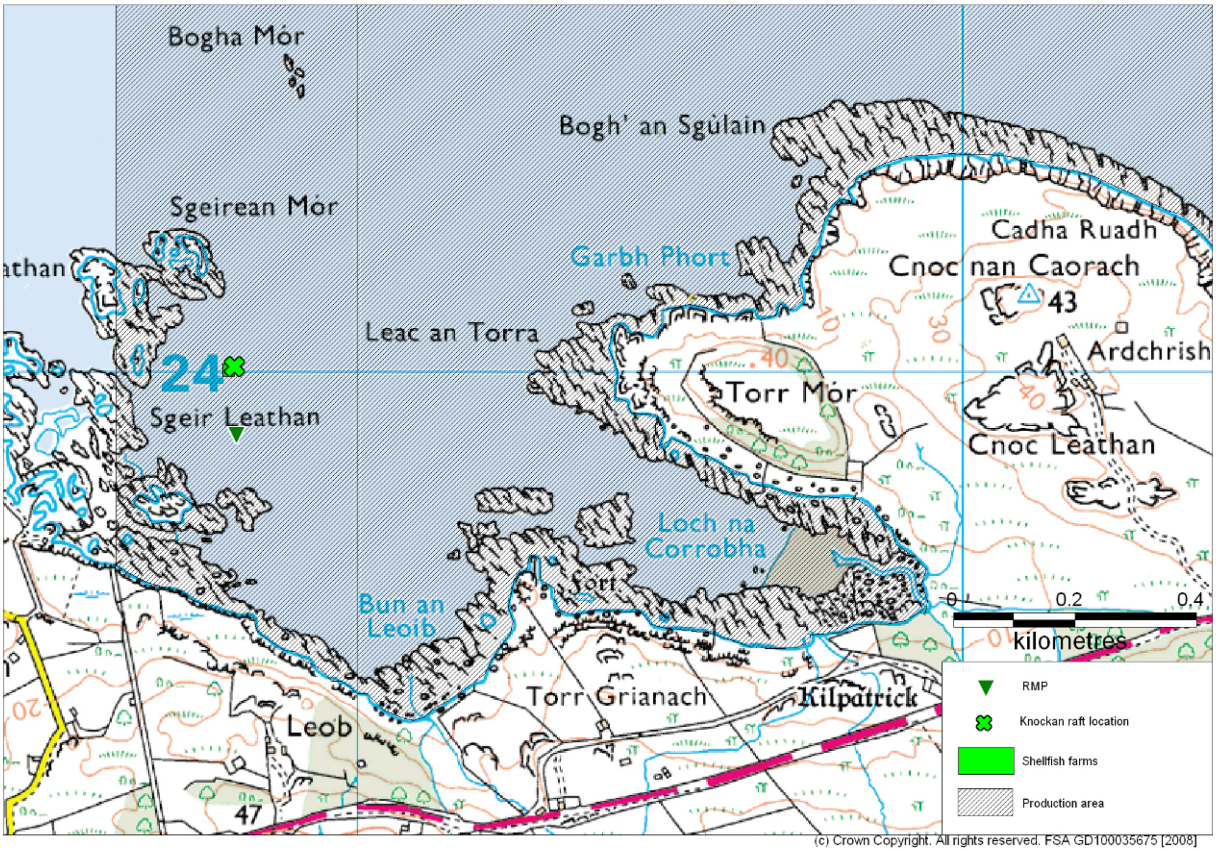


Figure 10.2 Map detail of Loch Scridain West production area

11. Historical *E. coli* data

11.1 Validation of historical data

All mussel samples taken from Loch Scridain up to the end of 2006 were extracted from the database and validated according to the criteria described in the standard operating procedure for validation of historical *E. coli* data. No samples were rejected on the basis of geographical discrepancies.

For Loch Scridain East, 20 samples had the result reported as <20, and were assigned a nominal value of 10, and in the one instance the result was reported as >18000, it was assigned a nominal value of 36000 for statistical assessment and graphical presentation.

For Loch Scridain East, 10 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 100 g of shellfish flesh and intervalvular fluid.

11.2 Summary of microbiological results by sites

All samples taken from Loch Scridain West were taken from the same sampling location throughout, at the RMP. Samples from Loch Scridain East were taken from both the RMP (in 2003 and 2004) and from another location 200 m north of the RMP for the rest of the time. A summary of sampling and results is presented in Table 11.1, and a map presenting the geometric mean result by year is presented in Figure 11.1. A further map illustrating the relative locations of the three sampling points is presented in Figure 11.2. The results obtained from the samples taken at the two locations at Loch Scridain East are presented together for clarity.

Table 11.1 Summary of results from Loch Scridain

Sampling Summary					
Production area	Loch Scridain East (A)	Loch Scridain East (B)	Loch Scridain East	Loch Scridain West	Both
Site	Loch Scridain	Loch Scridain	Loch Scridain	Knockan	All
Species	Common mussels	Common mussels	Common mussels	Common mussels	Common mussels
SIN	AB31405408	AB31405408	AB31405408	AB31505308	AB314 and AB315
Location sampled	NM455248	NM455250	Both combined	NM408239	All
Location of RMP					
Total no. of samples	53	16	69	66	135
No. 1999	4	0	4	5	9
No. 2000	7	0	7	5	12
No. 2001	9	0	9	6	15
No. 2002	11	0	11	10	21
No. 2003	2	8	10	11	21
No. 2004	1	7	8	10	18
No. 2005	9	1	10	10	20
No. 2006	10	0	10	9	19
Results Summary (*E. coli* mpn/100g)					
Minimum	<20	<20	<20	<20	<20
Maximum	9100	>18000	>18000	3500	>18000
Median	20	20	20	40	40
Geometric mean	58.8	49.6	56.6	49.9	53.2
90 percentile	750	1280	750	310	500
95 percentile	1480	10800	2140	452.5	1300
No. exceeding 230/100g	11 (21%)	2 (13%)	13 (19%)	9 (14%)	22 (16%)
No. exceeding 1000/100g	4 (8%)	2 (13%)	6 (9%)	2 (3%)	8 (5%)
No. exceeding 4600/100g	2 (4%)	1 (7%)	3 (4%)	0 (0%)	3 (2%)
No. exceeding 18000/100g	0 (0%)	1 (7%)	1 (1%)	0 (0%)	1 (1%)

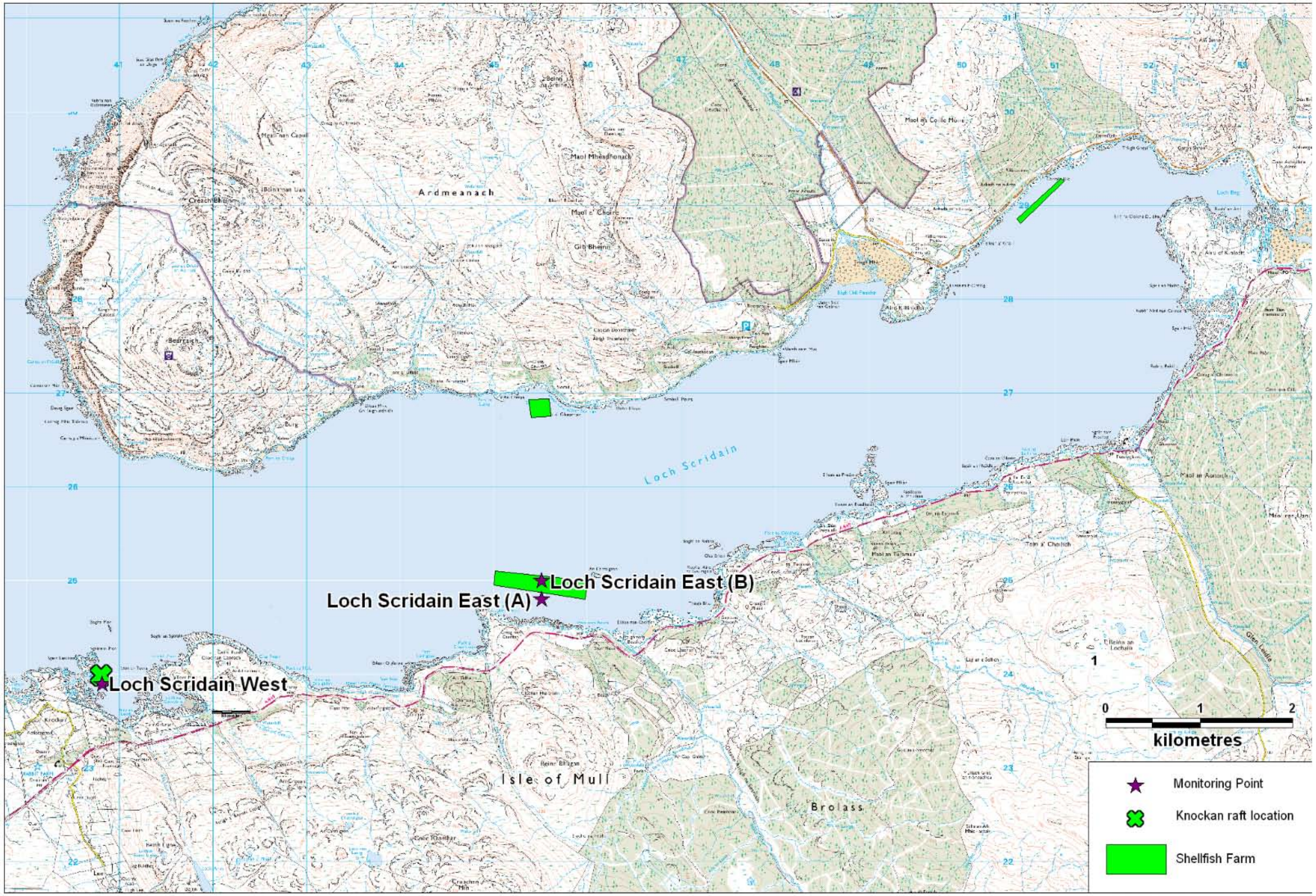


Figure 11.1 Map showing relative locations of historical monitoring points at Loch Scridain

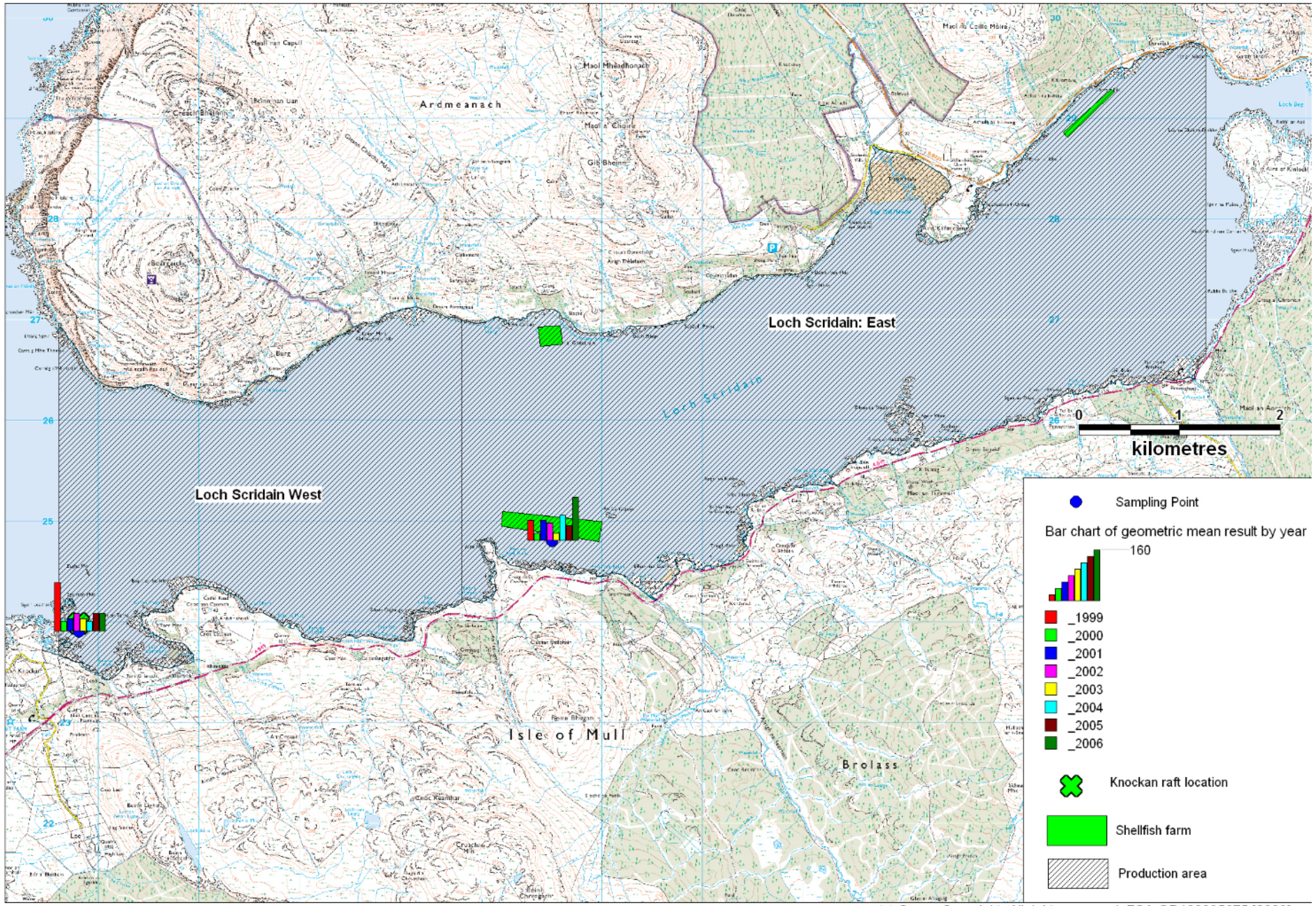


Figure 11.2 Map showing sampling location and geometric mean *E. coli* result by year (both sample points for Loch Scridain East combined)

The temporal pattern of sampling is very similar for Loch Scridain East and Loch Scridain West. The geometric mean result is also very similar (56.6 and 49.9 *E.coli* mpn/100g respectively), and no significant difference between the results for the two production areas was found (T-test, T-value=0.45, p=0.655, Appendix 11). On 51 occasions, both sites were sampled on the same day and hence under the same environmental conditions, thus permitting a more robust comparison of results. When these were compared there was no significant difference between areas (Paired T-test, T-value=0.58, p=0.563, Appendix 11). Figure 11.2 presents a boxplot of results obtained by area. Highest peak results were found at Loch Scridain East, where 3 samples exceeded 4600 *E. coli* mpn/100g. No results exceeded 4600 *E. coli* mpn/100g for Loch Scridain West. On two of the three occasions when a result of >4600 was obtained for Loch Scridain East, Loch Scridain West was also sampled on the same day. When results of 9100 and >18000 *E. coli* mpn/100g were obtained for Loch Scridain East, results of 3500 and 40 *E. coli* mpn/100g respectively were obtained at Loch Scridain West.

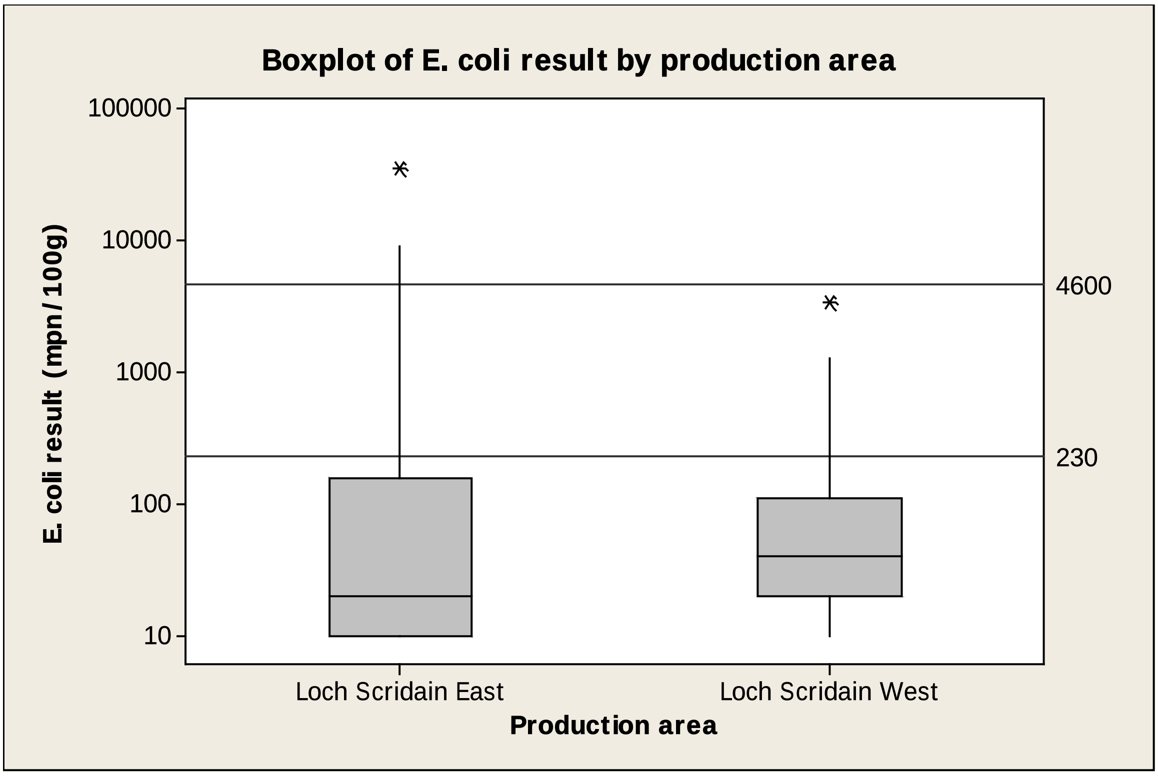


Figure 11.3 Boxplot of monitoring results obtained by area

11.3 Temporal pattern of results

Figures 11.4 and 11.5 present scatter plots of individual results against date for all samples taken from Loch Scridain. Both are fitted with trend lines to help highlight any apparent underlying trends or cycles. Figure 11.4 is fitted with a line indicating the geometric mean of the previous 5 samples, the current sample and the following 6 samples. Figure 11.5 is fitted with a loess smoother, a regression based smoother line calculated by the Minitab statistical software. Figures 11.6 and 11.7 present the same data presented separately by production area. Figure

11.8 presents the geometric mean of results by month (+ 2 times the standard error).

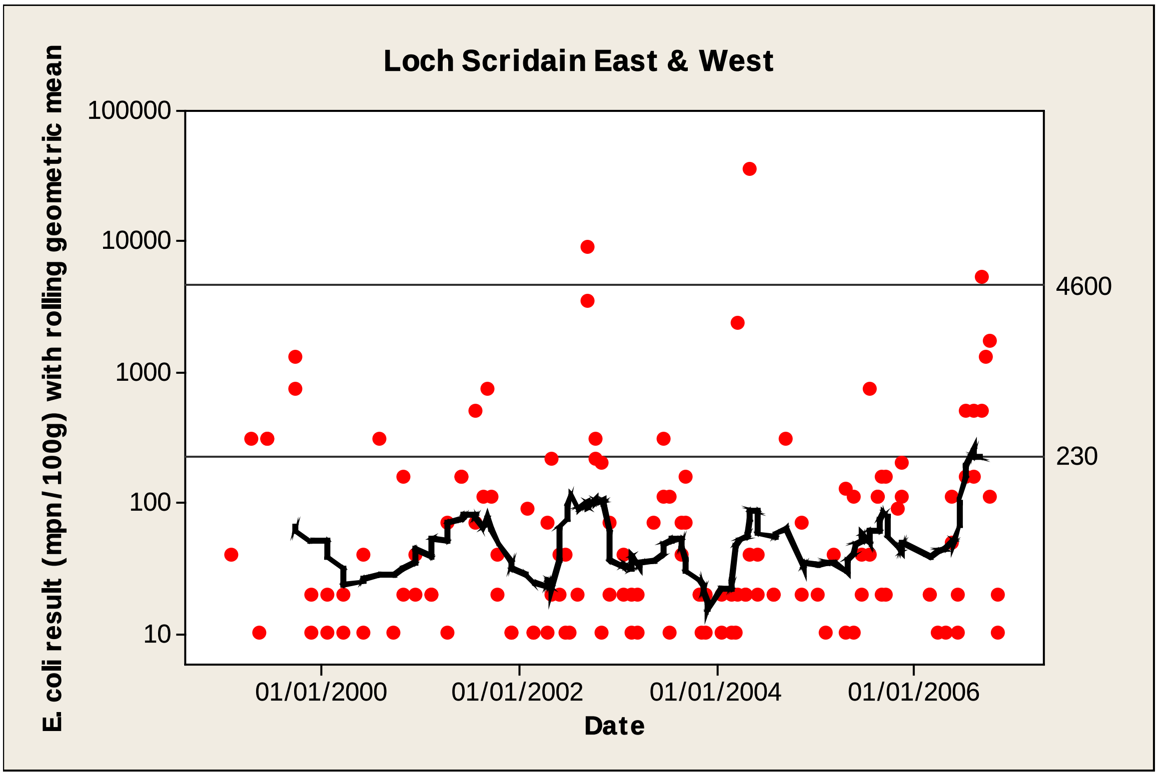


Figure 11.4 Scatterplot of results by date with rolling geometric mean

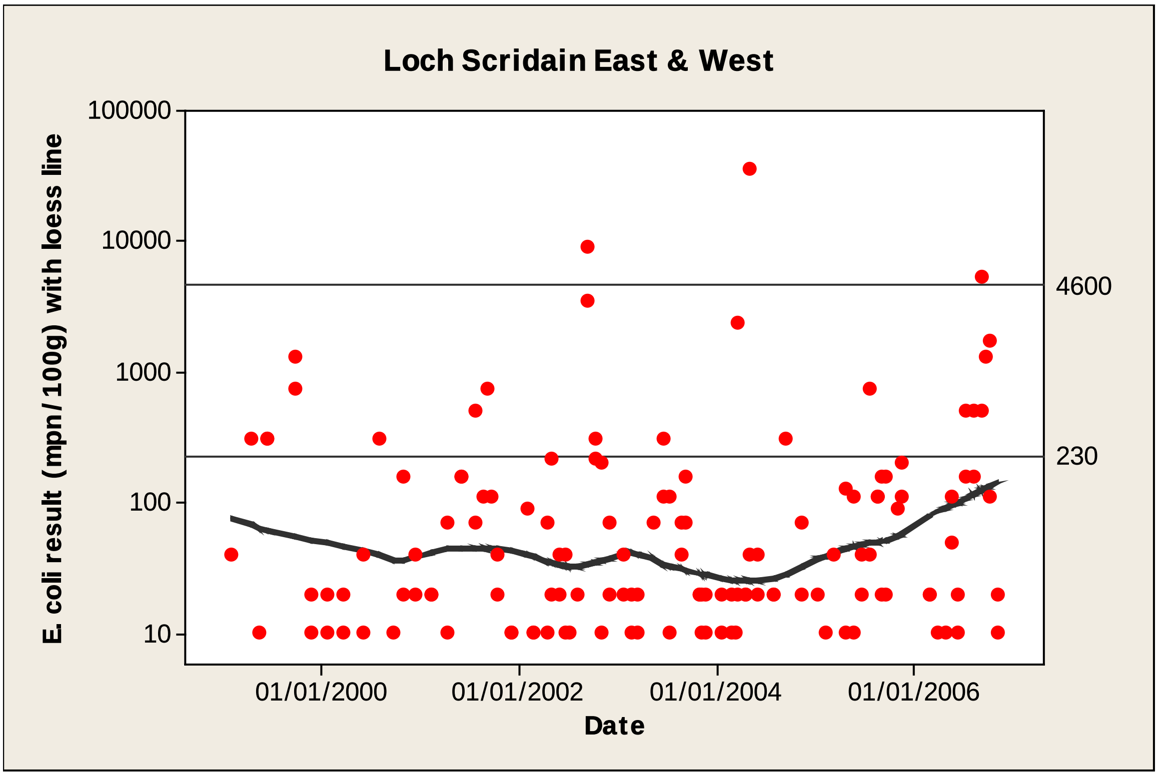


Figure 11.5 Scatterplot of results by date with loess smoother

Figure 11.4 suggests an annual cycle with higher results towards the middle of the year. No overall trends in microbiological quality are apparent in either 11.4 or 11.5, aside from a possible slight deterioration in results in 2006.

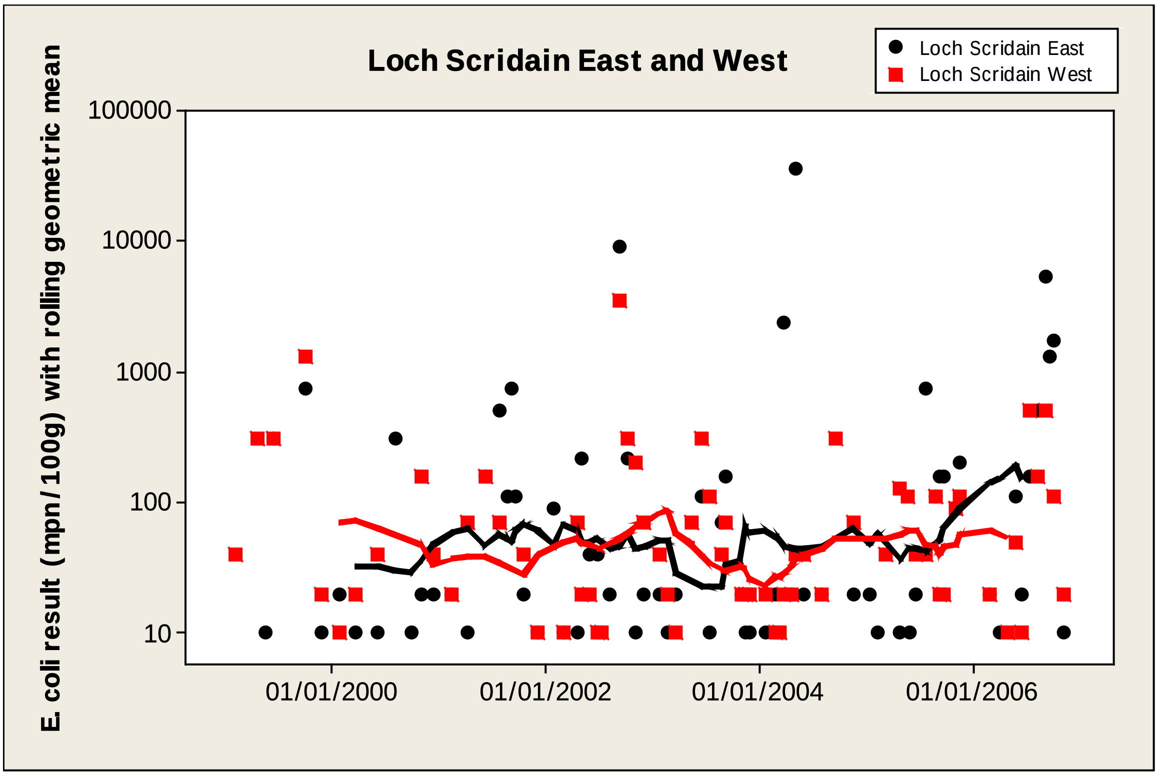


Figure 11.6 Scatterplot of results by date with rolling geometric mean by individual production area

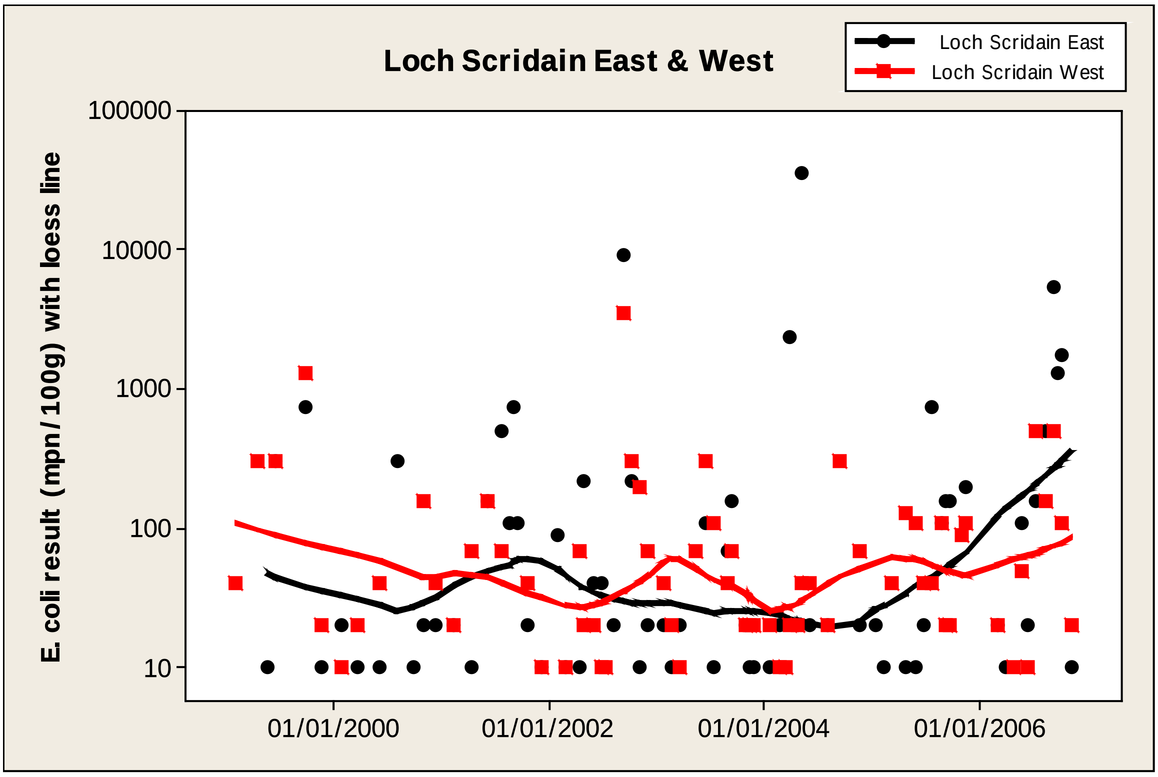


Figure 11.7 Scatterplot of results by date with loess smoother by individual production area

The apparent annual cycles seen in Figure 11.4 is not so obvious when the results by production area are presented separately. The possible deterioration in results in 2006 is more apparent for the Loch Scridain East production area.

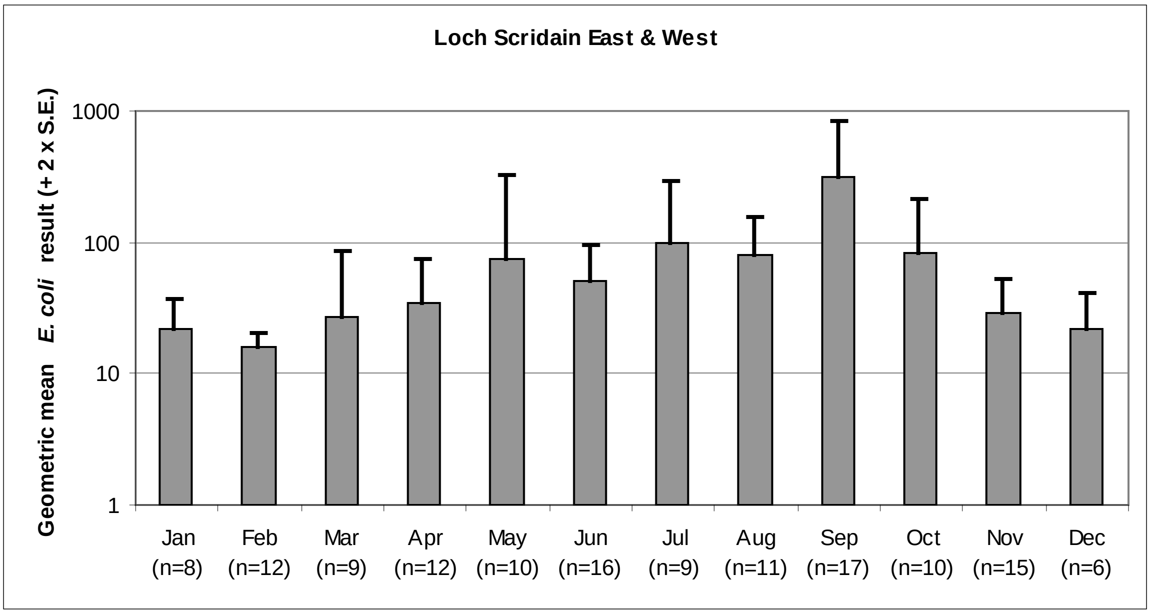


Figure 11.8 Geometric mean result by month

Highest mean results occurred in September, and lowest mean results occurred from November to February.

11.4 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. This analysis considers the 135 samples taken from Loch Scridain from 1999 to 2006 inclusive.

11.4.1 Analysis of results by season

Although not strictly an environmental variable in the same way as rainfall for example, season dictates not only weather patterns, but livestock numbers and movements, presence of wild animals and patterns of human occupation. Seasons were split into spring (March - May), summer (June - August), autumn (September - November) and winter (December - February).

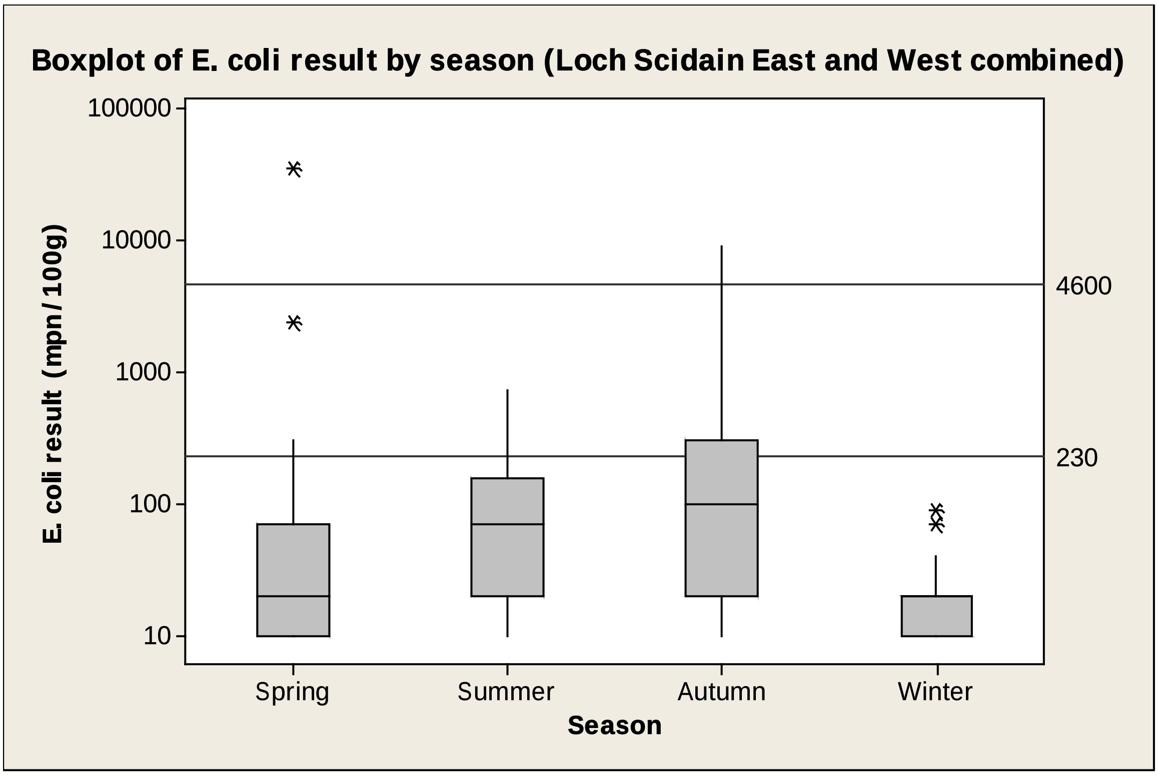


Figure 11.9 Boxplot of result by season (both production areas combined)

A difference was found between results by season (One-way ANOVA, p=0.000, Appendix 4). A post ANOVA test (Tukeys comparison, Appendix 4) identified significantly lower results occur in the winter compared to the summer and autumn.

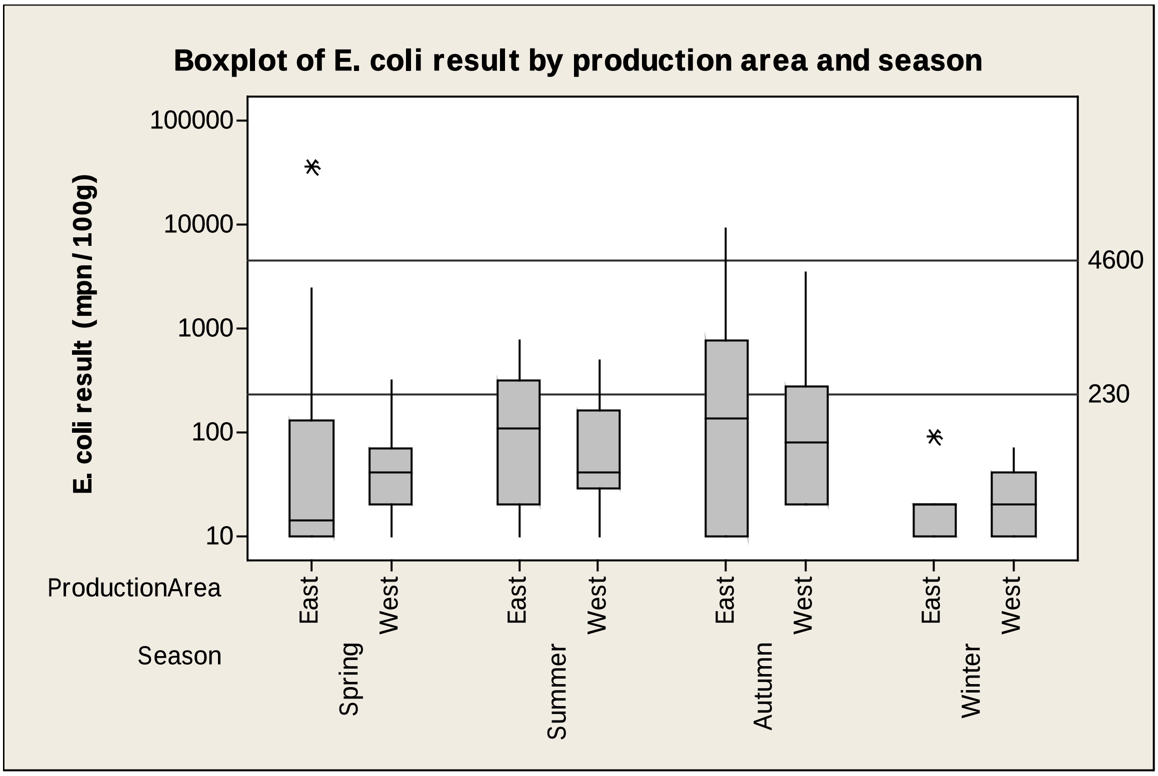


Figure 11.10 Boxplot of result by season for individual production areas

The two production areas have held different seasonal classifications in the past, suggesting some difference in the seasonality of results. When considered separately, results were again found to differ by season (Loch Scridain East: One-way ANOVA, p=0.044, Appendix 4. Loch Scridain West: One-way ANOVA, p=0.007, Appendix 4.). For both production areas, a post ANOVA test (Tukeys comparison, Appendix 4) identified significantly lower results occur in the winter compared to the autumn. Thus, both areas have a similar seasonal pattern, but the effect appears slightly stronger for Loch Scridain West.

11.4.2 Analysis of results by recent rainfall

The nearest weather station is located at Mull: Gruline, approximately 13 km to the north east of the production area. Rainfall records were available for the period 1/1/2003 to 31/10/2006 (total daily rainfall in mm), although total daily rainfall was not recorded on 61 days of this period.

The coefficient of determination was calculated for *E. coli* results and rainfall in the previous 2 days at Gruline. Figure 11.7 presents a scatterplot of *E. coli* result and rainfall. Figure 11.8 presents a boxplot of results by rainfall quartile (quartile 1 = 0 to 0.5 mm, quartile 2 = 0.5 to 5.6 mm, quartile 3 = 5.6 to 16.25 mm, quartile 4 = more than 16.25 mm).

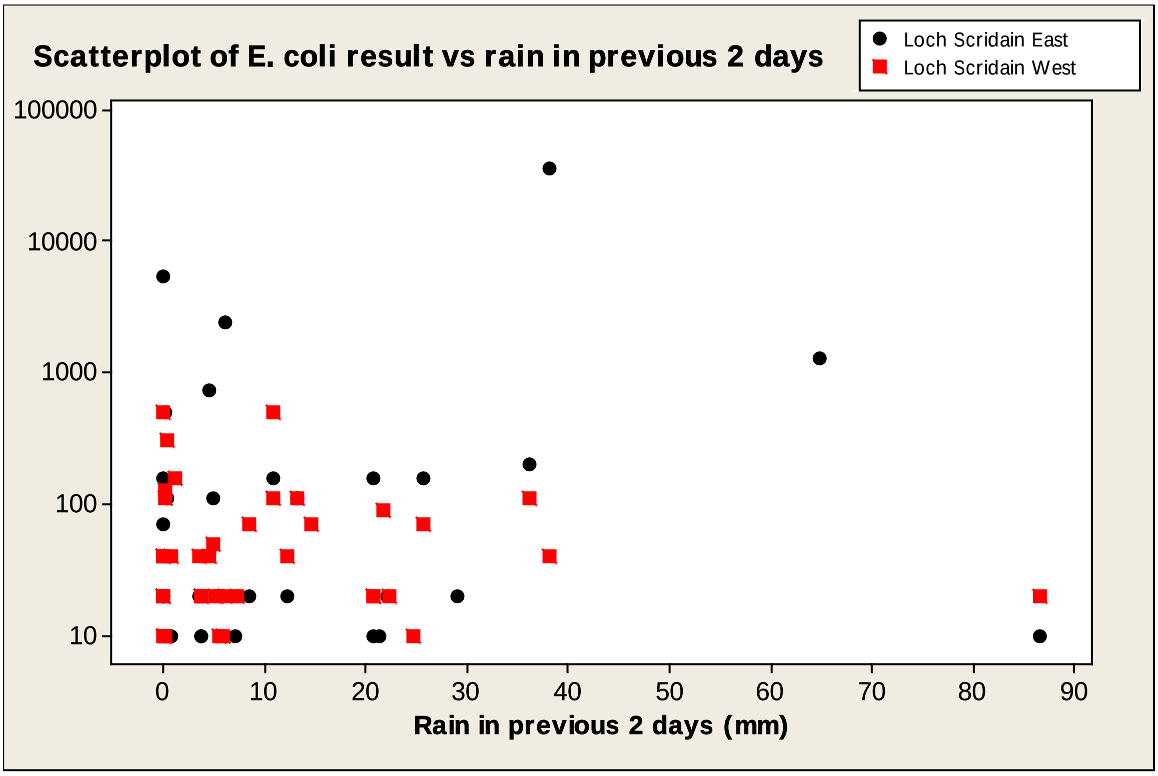


Figure 11.11 Scatterplot of result against rainfall in previous 2 days

The coefficient of determination indicates that there was no relationship between the *E. coli* result and the rainfall in the previous two days when both sites are considered together (Adjusted R-sq=0.0%, p=0.474, Appendix 4). When the areas were considered separately, the coefficient of determination indicated that there was no relationship between the *E. coli* result and the rainfall in the previous two days for either Loch Scridain East (Adjusted R-sq=0.0%, p=0.342, Appendix 4) or Loch Scridain West (Adjusted R-sq=0.0%, p=0.599, Appendix 4).

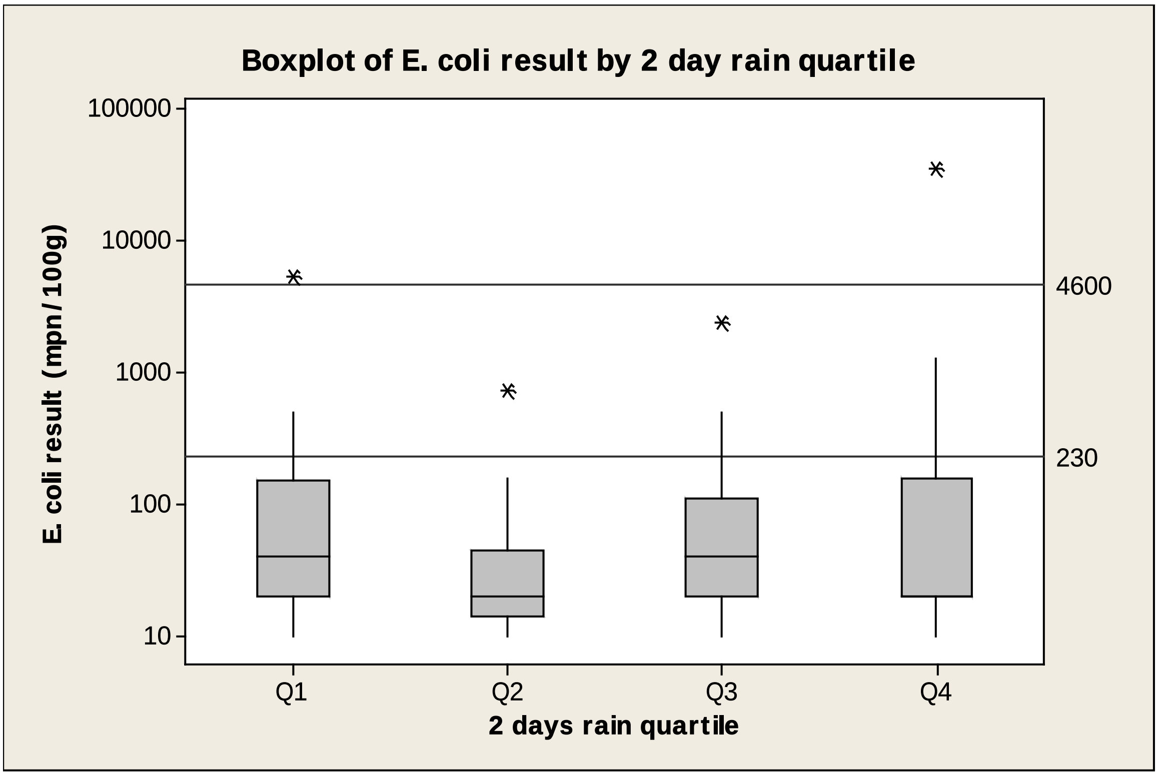


Figure 11.12 Boxplot of result by rainfall in previous 2 days quartile (both areas combined)

No significant difference was found between the results for each rain quartile (One way ANOVA, p=0.598, Appendix 4).

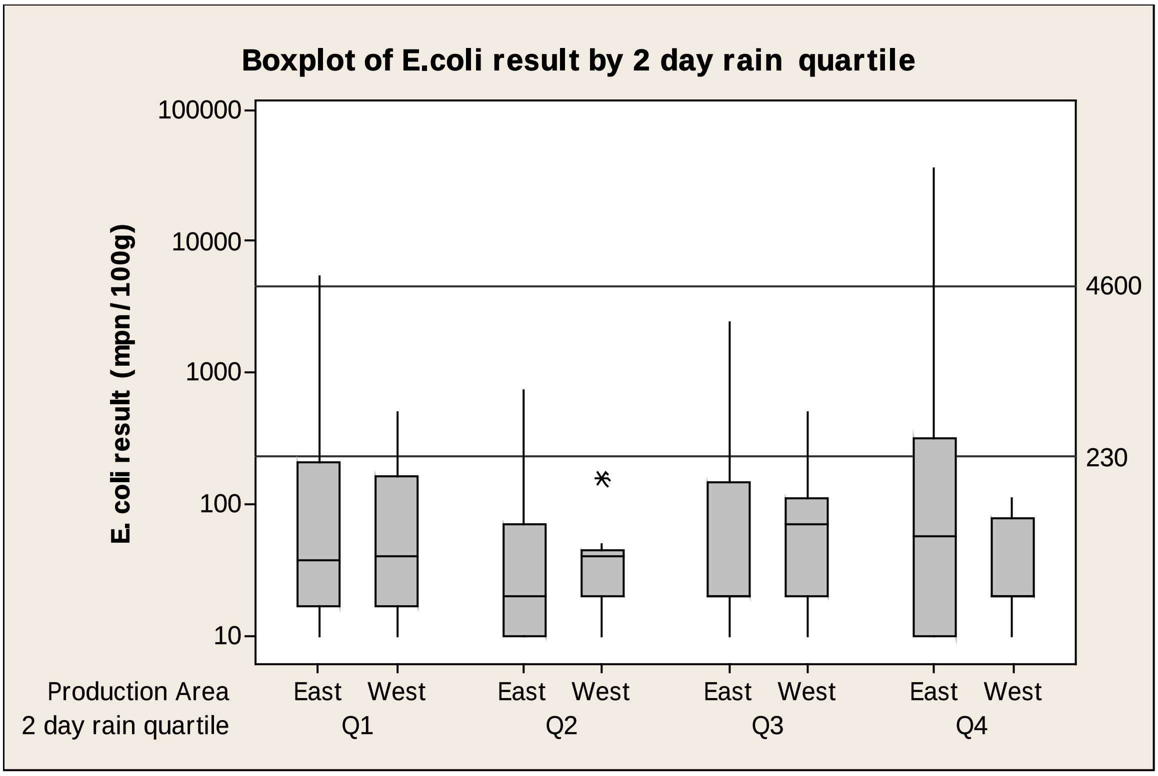


Figure 11.13 Boxplot of result by rainfall in previous 2 days quartile and production area

When considered separately, no significant difference was found between the results for each rain quartile for either Loch Scridain East (One way ANOVA, p=0.672, Appendix 4) or Loch Scridain West (One way ANOVA, p=0.594, Appendix 4).

As the effects of heavy rain may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationship between rainfall in the previous 7 days and sample results for Loch Scridain was investigated in an identical manner to the above. Interquartile ranges for 7 days rainfall were as follows; quartile 1 = 0 to 12.5 mm; quartile 2 = 12.5 to 31 mm; quartile 3 = 31 to 54 mm; quartile 4 = more than 54 mm.

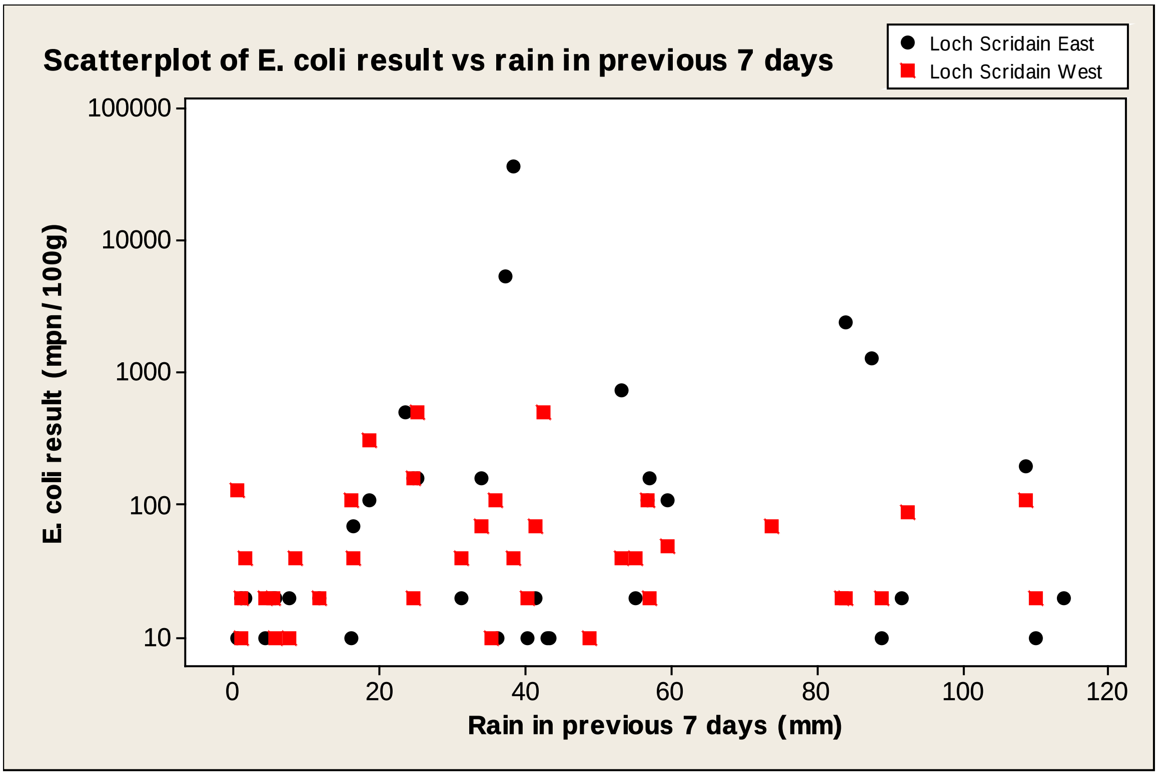


Figure 11.14 Scatterplot of result against rainfall in previous 7 days

The coefficient of determination indicates that there was no relationship between the *E. coli* result and the rainfall in the previous seven days (Adjusted R-sq=0.5%, p=0.245, Appendix 4). When the areas were considered separately, the coefficient of determination indicated that there was no relationship between the *E. coli* result and the rainfall in the previous two days for either Loch Scridain East (Adjusted R-sq=0.5%, p=0.288, Appendix 4) or Loch Scridain West (Adjusted R-sq=0.0%, p=0.731, Appendix 4).

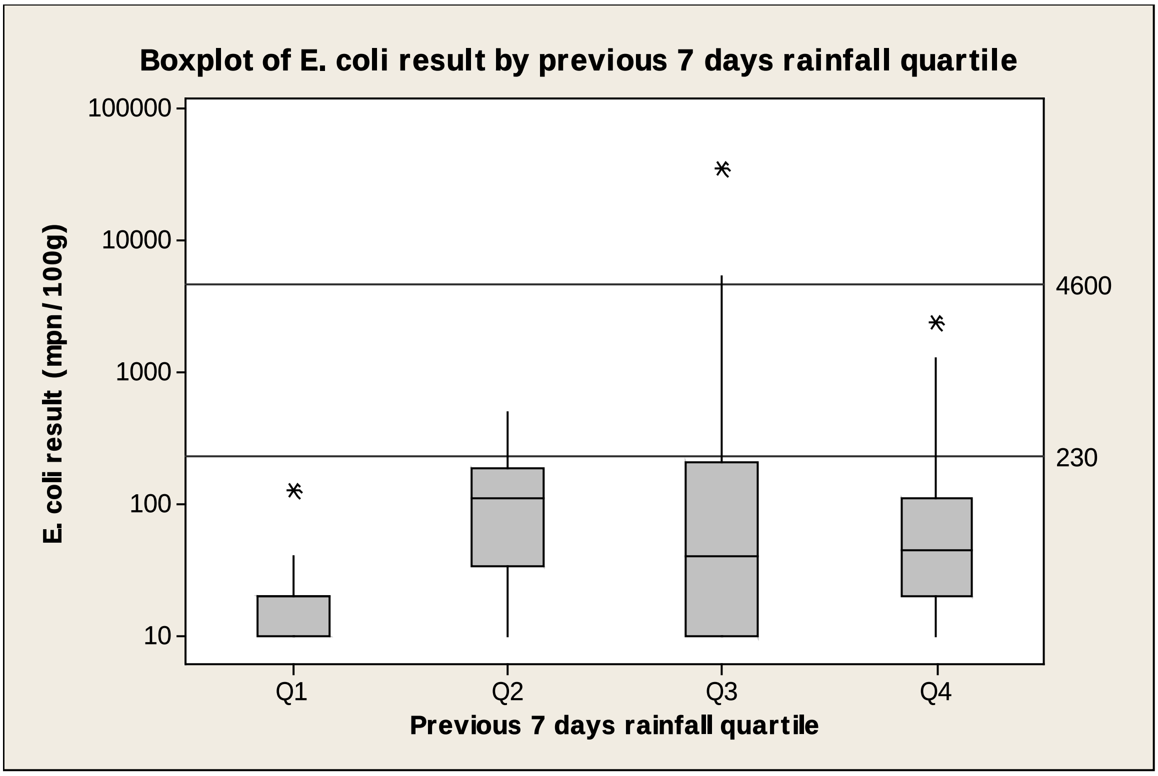


Figure 11.15 Boxplot of result by rainfall in previous 7 days quartile

A difference was found between results for each quartile (One way ANOVA, p=0.024, Appendix 4). A post ANOVA test (Tukeys comparison) shows results for quartile 1 are significantly lower than those for quartile 2 (but not quartiles 3 or 4). This shows that 7 days after a light rainfall (Q1), there is virtually no increase in *E.coli* concentrations above the LOD of the test. After higher amounts of rainfall, bacterial concentrations appear to be elevated.

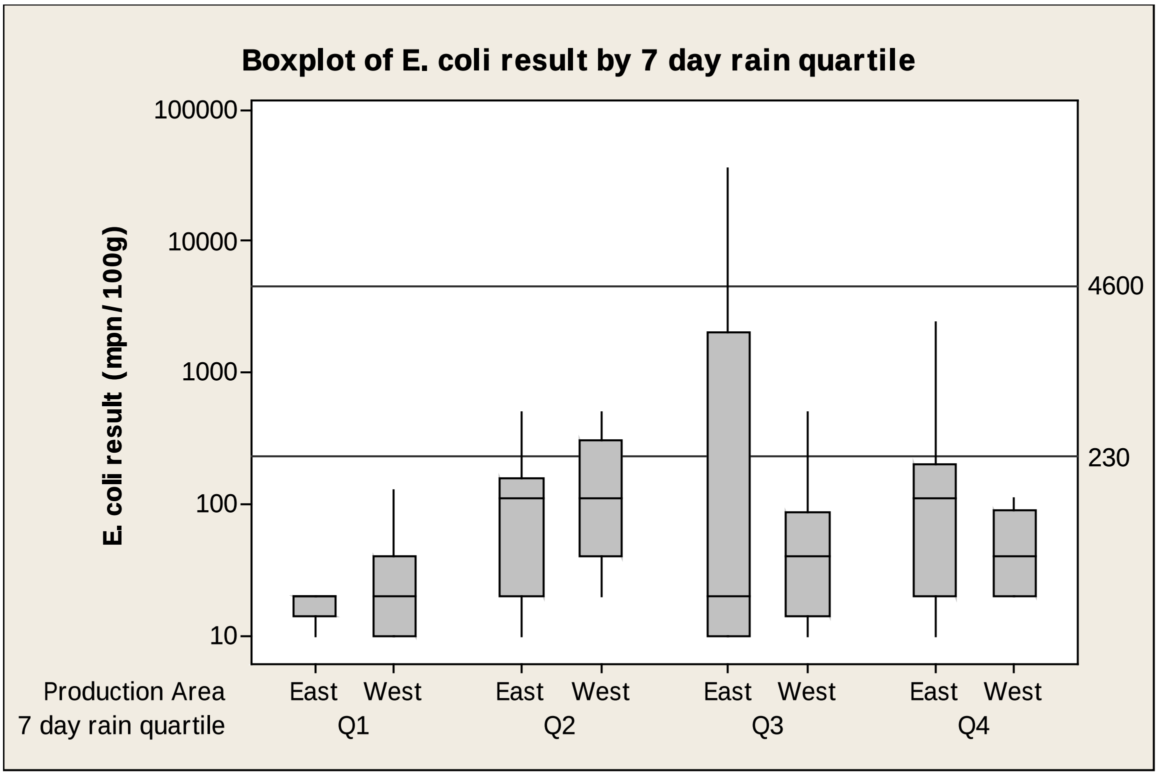


Figure 11.16 Boxplot of E. coli result by 7 day rainfall quartile and production area

When considered separately, no significant difference was found between the results for each rain quartile for Loch Scridain East (One way ANOVA, p=0.189, Appendix 4). For Loch Scridain West a significant difference was found between quartiles (One way ANOVA, p=0.039, Appendix 4). A post ANOVA test (Tukeys comparison) shows results for quartile 1 are significantly lower than those for quartile 2 (but not quartiles 3 or 4), the same pattern previously observed when both production areas were considered in the analysis.

Overall, no relationship between *E. coli* result and rainfall in previous 2 days was detected, but a relationship between E. coli result and rainfall in the previous 7 days was detected for Loch Scridain West only. The influence of rainfall on microbiological quality will depend on factors such as fishery location, local geology, topography and land use.

11.4.3 Analysis of results by lunar state

Lunar state dictates tide size, with the largest tides occurring 2 days after either a full or new moon. With the larger tides, circulation of water in the area will increase, and more of the shoreline will be covered, potentially washing more faecal contamination from livestock into the loch. The vast majority of samples gathered from Loch Scridain were collected on the larger (79%) or medium sized tides (20%). As a consequence, no analysis of the effects of tide size was carried out.

11.4.4 Water temperature

Water temperature is likely to affect the survival time of bacteria in seawater (Burkhardt *et al*, 2000) and presumably 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.

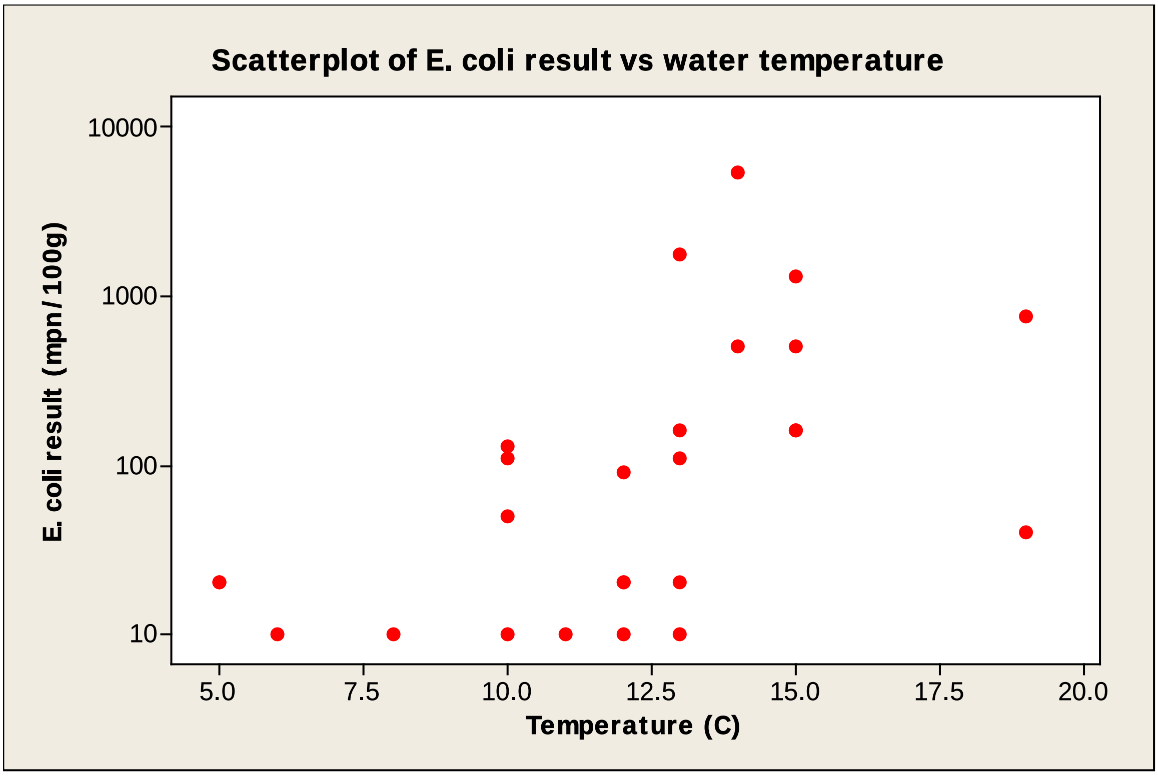


Figure 11.17 Scatterplot of result against water temperature at time of sampling

The coefficient of determination indicates that there was a weak positive relationship between the *E. coli* result and the water temperature at time of sampling (Adjusted R-sq=25.7%, p=0.005, Appendix 4). This is consistent with the seasonal pattern, and suggests that contamination is higher in the warmer months and/or bacteria are accumulated more effectively in warmer water.

11.4.5 Wind direction

Wind speed and direction may change water circulation patterns in the production area. Mean wind direction for the 7 days prior to each sample being collected was calculated from wind data recorded at the Tiree weather station (where data was available), and mean result by mean wind direction in the previous 7 days is plotted in Figure 11.18.

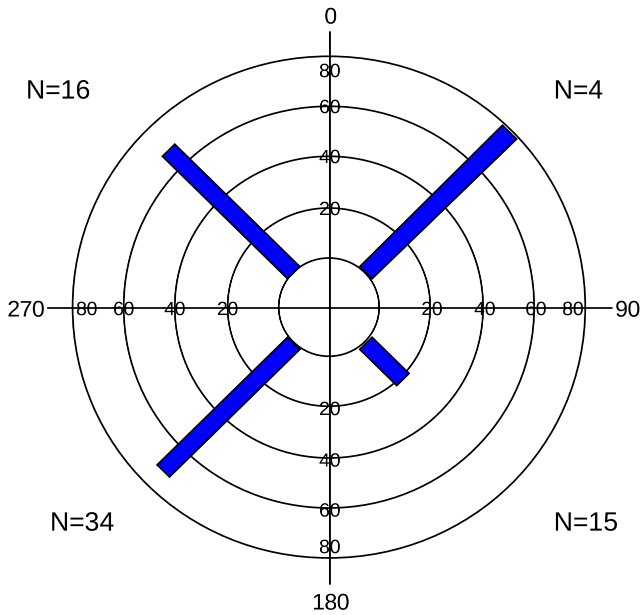


Figure 11.18 Circular histogram of geometric mean *E. coli* result by wind direction

A significant correlation between wind direction and *E. coli* result was found (circular-linear correlation, r=0.275, p=0.007, Appendix 4), with lowest results occurring when the wind was in a south easterly direction. Mean result was similar for the other three wind directions, although it must be noted that very few samples were collected when the wind was in a north easterly direction. Of the two results over 4600 *E. coli* mpn/100g for which wind data was available, one occurred when the wind was blowing from a south westerly direction, and one occurred when the wind was blowing from a north westerly direction.

11.4.6 Summary of environmental effects

A strong relationship between season and results was found, with results higher in the summer and autumn compared to the winter suggesting that either inputs are higher in summer and autumn and/or the uptake of bacteria by the shellfish is higher in warmer water.

The only relationship found between results and recent rainfall was that results were lower following a 7 day period of drier weather (quartile 1) compared to a 7 day period of light-moderate rainfall (quartile 2), with heavier rainfall (quartiles 3 and 4) giving intermediate results. This only applied at Loch Scridain West when the two sites were considered separately.

Influence of lunar state (tide size) could not be investigated.

A positive relationship between water temperature and level of contamination was found. Again, this suggests that either inputs were higher in summer and autumn and/or the accumulation of bacteria by the shellfish was higher in warmer water.

Results were lowest when the wind had been blowing from a south easterly direction compared to other directions.

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.

Aside from the seasonality of results suggesting that sampling should be continued on a monthly basis, these findings have no material bearing on the sampling plan.

11.5 Sampling frequency

When a production area has had 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 may be decreased from monthly to bimonthly. This is not appropriate for either of the production areas within Loch Scridain, as they have held seasonal classifications in 2005 and 2007.

12. Designated Shellfish Growing Waters Data

The area considered in this report is also a SEPA shellfish growing water which was designated in 2002. The extent of this and the location of the SEPA designated monitoring point are shown on figure 12.1.

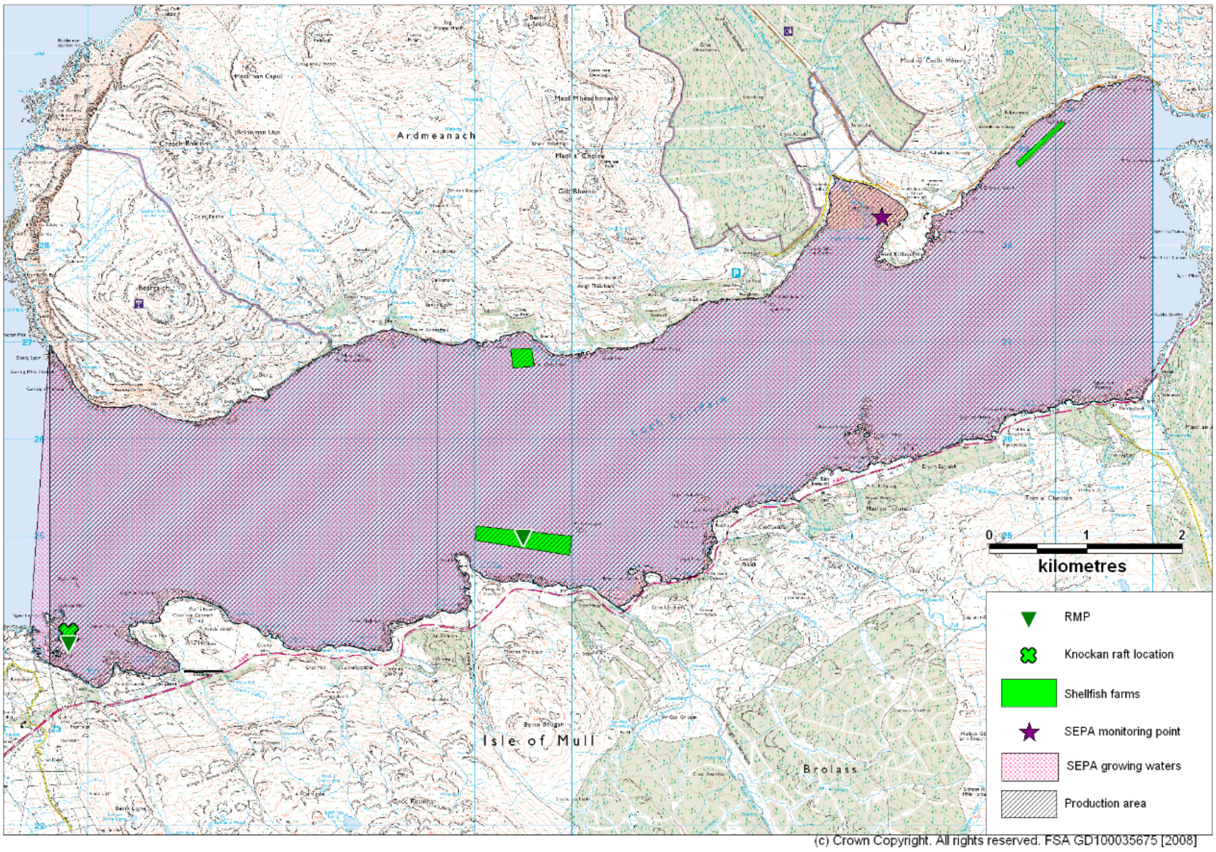


Figure 12.1 Map showing SEPA designated growing water and monitoring point

The monitoring requires the following testing:

- Quarterly for salinity, dissolved oxygen, pH, temperature and visible oil
- Twice yearly for metals in water
- Annually for metals and organohalogens in shore mussels
- Quarterly for faecal coliforms in shore mussels

Monitoring of the area started in the last quarter of 2002, and results to the end of 2006 have been provided by SEPA. Monitoring results for faecal coliforms are presented in Table 12.1.

Table 12.1. SEPA Faecal coliform results (FC/100g) for shellfish gathered from Loch Scridain.

	Site	Loch Scridain	Loch Scridain
	OS Grid Ref.	NM 49200 28300	NM 408 239
2002	Q1	-	-
	Q2	-	-
	Q3	-	-
	Q4	-	20
2003	Q1	-	20
	Q2	-	-
	Q3	1300	-
	Q4	310	-
2004	Q1	20	-
	Q2	310	-
	Q3	500	-
	Q4	310	-
2005	Q1	40	-
	Q2	>18000*	-
	Q3	5400	-
	Q4	500	-
2006	Q1	40	-
	Q2	>18000	-
	Q3	91000	-
	Q4	310	-

* Assigned a nominal value of 36000 for the purpose of calculating the geometric mean

The first two samples collected were taken from NM 408239, which is the RMP for Loch Scridain West. All other samples were taken from the SEPA monitoring point shown on Figure 12.1. The geometric mean result of all shore mussel samples taken from the SEPA monitoring point was 819 faecal coliforms / 100g. Results ranged from 20 to 91000 faecal coliforms / 100g.

Levels of faecal coliforms are usually closely correlated to levels of *E. coli* often at a ratio of approximately 1:1. The ratio depends on a number of factors, such as environmental conditions and the source of contamination and as a consequence the results presented in Table 12.1 are not directly comparable with other shellfish testing results presented in this report. The geometric mean level of contamination in shore mussels taken from the SEPA monitoring point is considerably higher than the overall geometric mean of the rope mussel samples tested for *E. coli* (53.2 mpn/100g) presented in Table 11.1. It might be expected that higher levels of contamination are found in the intertidal zone here, where a large watercourse enters the loch, livestock have access to the shoreline and there is human habitation, compared to rope mussels grown offshore.

Results for the physical and chemical parameters monitored by SEPA are not presented in this report.

13. Bathymetry and Hydrodynamics

Figure 13.1 Loch Scridain Bathymetry

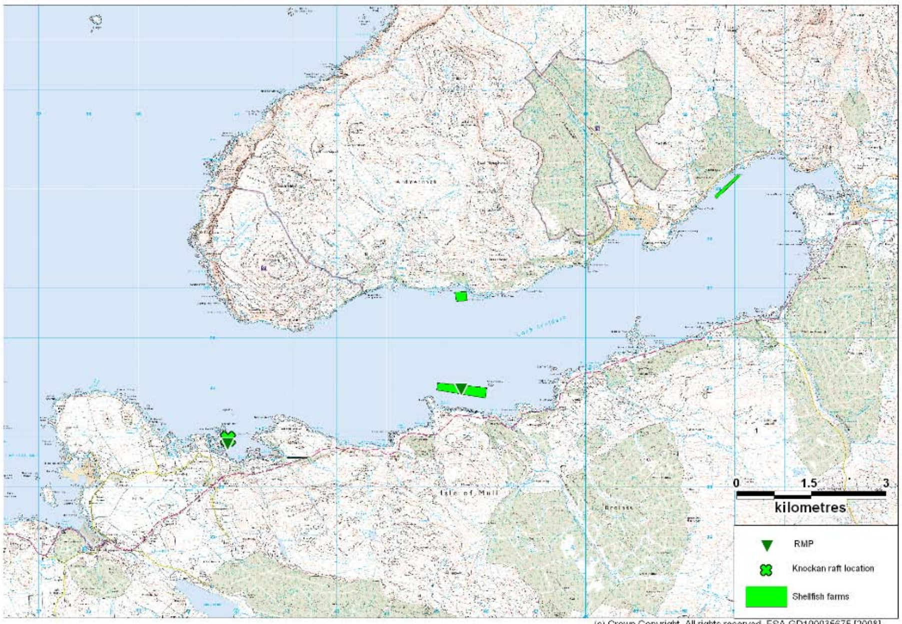


Figure 13.2 OS map of Loch Scridain

The bathymetry chart above shows that the depth ranges from less than 5 metres at the eastern end of the loch to more than 50 – 100 metres at the western end of the loch, close to the shellfish farm. There are drying areas around much of the coastline of the loch, with larger areas towards the eastern end.

The loch contains one sill, located approximately 3 km to the west of the shellfish farms at a narrowing of the loch entrance. The sill depth is 53 metres with a basin depth of 121 metres. The deepest part of the loch is a small area located just to the east of the sill, where it is likely that scouring occurs during tidal exchange. Depths are far shallower near the head of the loch.

Table 13.1 lists characteristics of Loch Scridain as published in the Catalogue of Scottish Sea Lochs.

Table 13.1 Loch Scridain characteristics

Loch length	12 km
Maximum depth	121 m
Volume (at low water)	754.7 million m^3
Fresh/tidal, per thousand	6.3
Mean depth at low water	29.8 m
Watershed	175 km^2
Runoff (million m^3/year)	305.5
Salinity Reduction	0.2 ppt
Flushing time	6 days
Sills	1
Sill depth	53 m
Basin depth	121 m

Source: Edwards & Sharples, Catalogue of Scottish Sea Lochs

The salinity reduction of 0.2 ppt is relatively low, indicating that fresh water flows into the loch are small by comparison with the loch volume. Contaminants carried via fresh water flow might likewise be expected to dilute significantly within the loch.

The flushing time of 6 days is relatively slow, which means that any contaminants entering the voe are not likely to be flushed from it for up to a week. However given the large volume of the loch it is expected that most contaminants within the loch will be substantially diluted.

13.1 Tidal Curve and Description

The two tidal curves below are for the port of Bunessan, which is located in the first inlet west of the opening of Loch Scridain. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 GMT on 05/09/07, the date of the shoreline survey. The second is for seven days beginning 00.00 GMT on 12/09/07. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle.

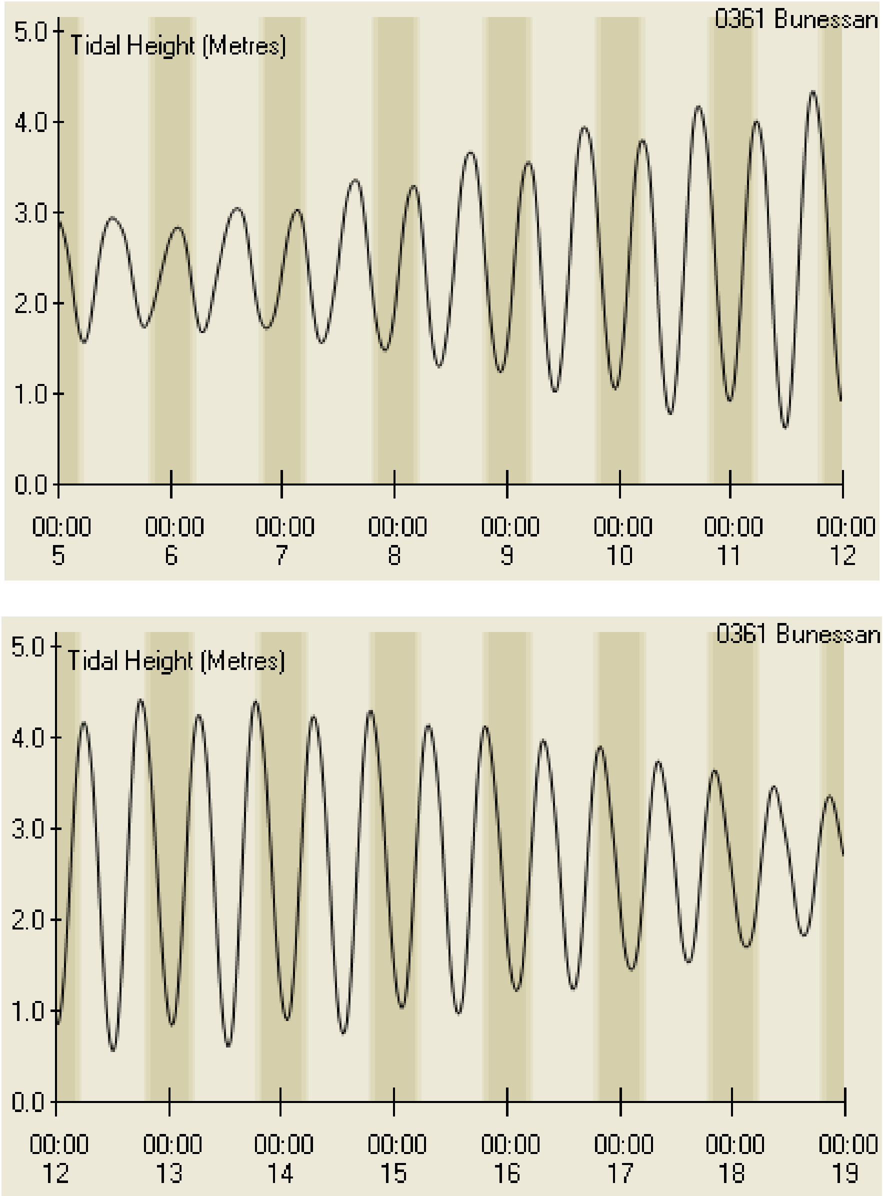


Figure 13.3 Tidal curves for Bunessan

The following is the summary description for Bunessan from TotalTide:

The tide type is Semi-Diurnal.

MHWS	4.3 m
MHWN	3.0 m
MLWN	1.8 m
MLWS	0.6 m

Predicted heights are in metres above chart datum. The tidal range at spring tide is therefore approximately 3.7 m and at neap tide 1.2 m.

13.2 Currents – Tidal Stream Software Output and Description

Tidal stream information is available for the Loch Scridain station SN036G, which lies just outside the mouth of the loch north of Bunessan and to the west of the farms. The table below shows the tidal stream information as recorded for 5th September 2007.

Table 13.2 Tidal stream information for SN036G

SN036G		
Time (GMT)	Speed (m/s)	Direction
01:00	0.13	307°
03:00	0.07	336°
05:00	0.07	101°
07:00	0.07	118°
09:00	0.07	150°
11:00	0.01	
13:00	0.08	289°
15:00	0.07	319°
17:00	0.02	
19:00	0.07	105°
21:00	0.07	118°
23:00	0.06	150°

Figure 13.4 shows the speed and direction of tides at times of highest and lowest current speeds on the date of the shoreline survey. Times are given in GMT without offset for daylight savings time.

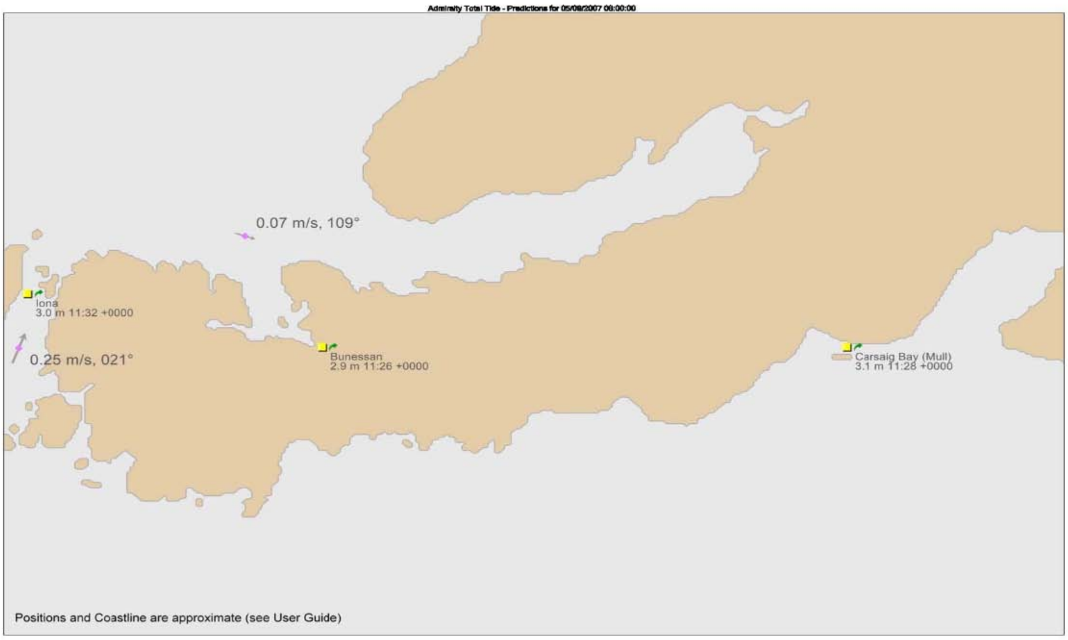
Current speeds are relatively slow at the entrance to the loch on both the ebb and flood tides.

13.3 Conclusions

The larger of the two existing shellfish farms lies just to the east of a small headland that will affect current strength and movement across the farm, where currents are likely to form an eddy in the lee of the headland during tidal exchange. This may affect movement of contaminants from south and east of the farm on an outgoing tide. As the nearest known sources of contamination are two streams to the southeast of the farm, these would be expected to impact on the bacteriological quality of shellfish grown there particularly during and immediately after an outgoing tide.

The farm at the Knockan site lies in a sheltered bay west of the sill. It is not likely to be affected by contaminant sources from further up the loch. It is likely to be more acutely affected by local contaminant sources within the bay itself and less likely to be significantly impacted by known sources at Bunessan due to its distance (7km).

The fallow site near the head of the loch is likely to be more contaminated due to poor mixing and high freshwater input and its associated bacteriological load.



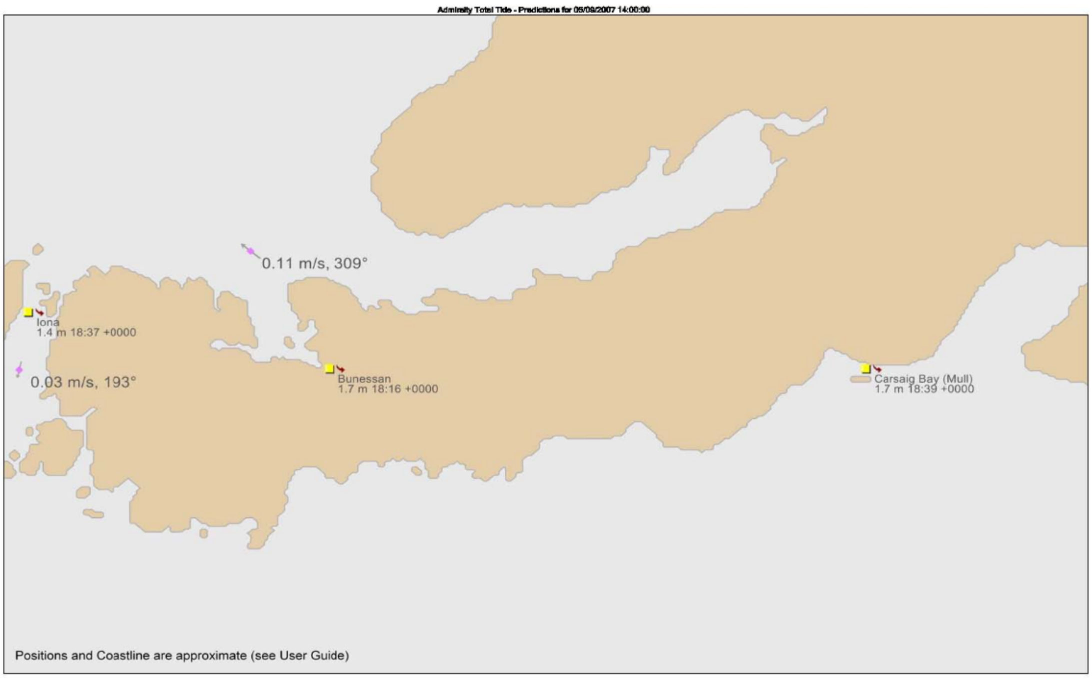


Figure 13.4 Tidal flows for Loch Scridain, 5th September 2007

14. River Flow

There are no river gauging stations on rivers or burns feeding into Loch Scridain.

The following rivers and streams were measured and sampled during the shoreline survey. These represent the largest freshwater inputs into Loch Scridain.

Table 14.1 River loadings for Loch Scridain

No	Grid Ref	Description	Month sampled	Width (m)	Depth (m)	Flow (m/s)	Flow in m3/day	*E.coli* (cfu/ 100ml)	Loading (*E.coli* per day)
1a	NM 54633 29133	Coladoir River	September	***	***	***	648000*	500	3.4×10^{12}
1b	NM 54654 29142	Coladoir River	November	***	***	***	***	<100	-
2a	NM 51853 26434	Leidle River	September	-	-	-	108000*	2900	3.1×10^{12}
2b	NM 51877 26426	Leidle River	November	5.28	0.33	0.485	73014	100	7.3×10^{10}
3	NM 38374 21928	Bunessan River	September	4.4	0.21	1	79834	1900	1.5×10^{12}
4	NM 53723 28310	Allt Fhearchair	September	2.7	0.18	1.2	50388	700	3.5×10^{11}
5	NM 54374 28447	Allt a Mhaim	September	4.5	0.27	1.1	115474	300	3.5×10^{11}
6a	NM 46556 24215	Beach River	September	15	0.2	0.8*	207360	100	2.1×10^{11}
6b	NM 46535 24219	Beach River	November	7.5	0.28	0.37	67133	<100**	3.4×10^{10}
7	NM 51518 26367	Allt na Crannaig	September	2.7	0.11	0.85	21812	800	1.7×10^{11}
8	NM 54034 28386	An Leith Allt	September	4.3	0.18	1	66874	200	1.3×10^{11}
9a	NM 48698 28714	Abhainn Bail a Mhuilinn	September	17	0.3	0.4*	176256	<100**	8.8×10^{10}
9b	NM 48723 28706	Abhainn Bail a Mhuilinn	November	15.88	0.13	0.205	36565	<100**	1.8×10^{10}
10	NM 51173 29509	Allt na Coille Moire	September	7.3	0.25	0.5	78840	100	7.9×10^{10}
11	NM 40626 23650	Stream	September	0.34	0.16	1.2	5640	1300	7.3×10^{10}
12	NM 48359 25333	Abhainn nan Torr	September	2.5	0.2	1.5	64800	<100**	3.2×10^{10}
13	NM 52371 27158	Allt Creag a Chromain	September	2	0.15	0.59	15293	200	3.1×10^{10}
14	NM 54377 29185	Allt a Ghlinne Dhuibh	September	4.6	0.14	1	55642	<100**	2.8×10^{10}
15	NM 44168 27477	Abhainn Beul-ath an Tairbh	September	8	0.12	1	82944	22	1.8×10^{10}
16	NM 41121 23428	Allt Loch Arm	September	1.5	0.14	0.64	11612	<100**	5.8×10^{9}
17	NM 44869 24195	Allt Chaomhain	September	1.65	0.09	0.8	10264	<100**	5.1×10^{9}
18	NM 41915 23635	Allt an t-Sluichd Odhair	September	3.2	0.11	0.33	10036	<100**	5.0×10^{9}
19	NM 47461 24724	An Leth-allt	September	1.9	0.1	0.33	5417	<100**	2.7×10^{9}
20	NM 51941 29730	Allt Eas in Ime	September	1.65	0.03	1	4277	<100**	2.1×10^{9}

* Visual estimate only
** Assigned a nominal value of 50 for the calculation of loading
*** Not possible to measure safely using available equipment due to size and depth

The catchment area for Loch Scridain is 175 km^2, which is relatively small given the area of the loch itself is 28.5 km^2. The largest freshwater input is the Coladoir River, at the head of the loch. It was not possible to measure discharge during the shoreline survey due to its large size. In addition to this many streams and small rivers discharge all around the loch. *E. coli* concentrations measured during the shoreline survey ranged from low to moderate (<100 to 2900 cfu/100ml). Where

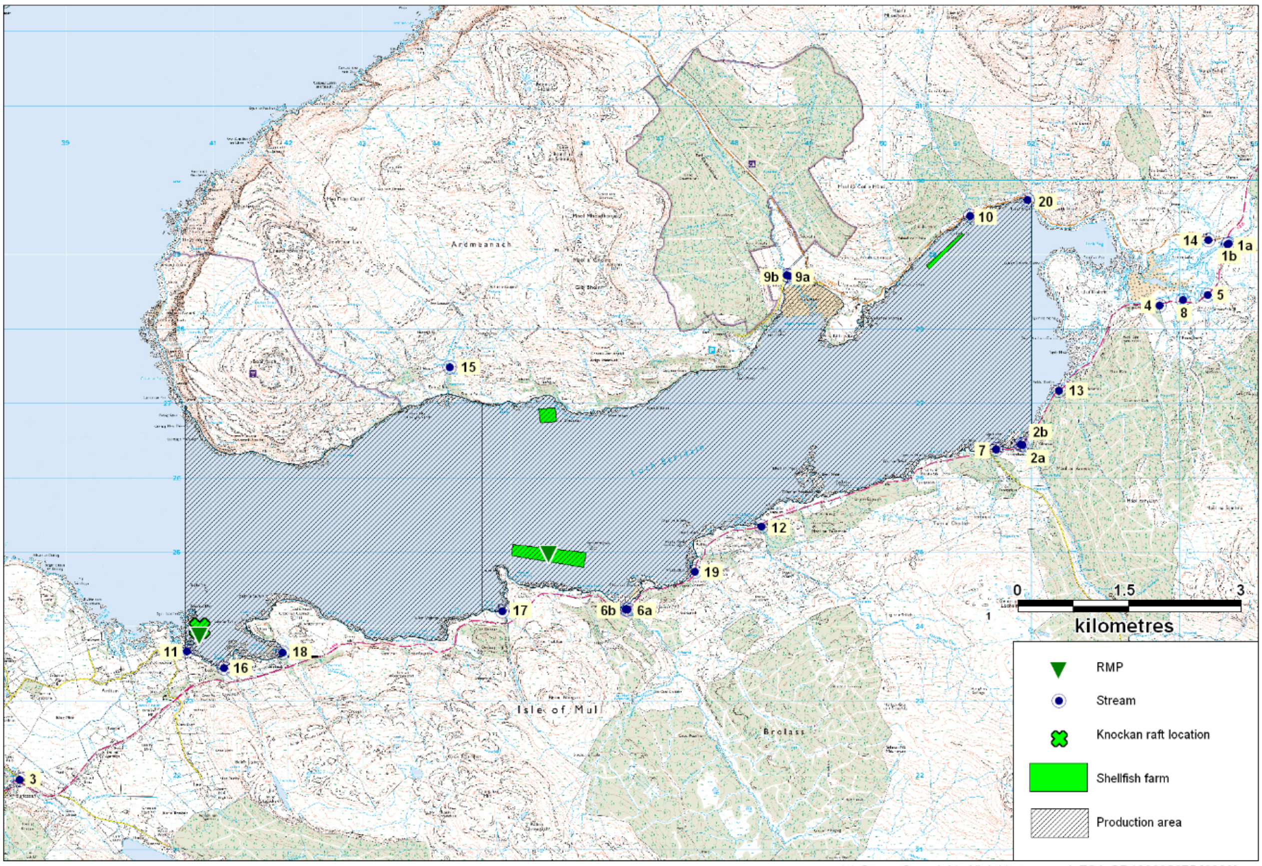


Figure 14.1 Map of significant streams and loadings

rivers were resampled during November, both flows and *E. coli* concentrations were lower.

The cumulative effect of these watercourses will significantly influence *E. coli* levels in Loch Scridain. The upper loch, which is much shallower and receives a large proportion of the freshwater inputs will be most heavily influenced by freshwater inputs, as demonstrated by the low salinity of water samples taken near the head of the loch during the shoreline survey. Nearer the mouth of the loch, where the shellfish farms are located, the freshwater influence will be much lower.

Faecal contamination carried by the Beach River is likely to significantly impact the main site at Loch Scridain. Loadings carried by the river were measured at 2.1×10^{11} at the date of main survey and this bacterial load discharges within 0.5 km of the southeast corner of the mussel farm. Wind and tidal conditions may also affect the movement of contaminants in this area.

Streams 11, 16 and 18 are most likely to affect the site at Knockan. Stream 11 discharges closest to the mussel raft (within 0.5 km) and carried a measured loading of 7.3×10^{10} *E. coli* per day at the time of sampling. This could significantly impact the water quality in this bay.

15. Shoreline Survey Overview

The shoreline survey was conducted on the 4th to 6th September 2007. A second visit was undertaken on the 26th November 2007 to re-measure four watercourses.

The loch consists of two separate production areas. Within the production area Loch Scridain West, lies one site named Knockan. This consists of a small raft from which 4 m lines are suspended. Within the production area Loch Scridain East, lies one site named Loch Scridain. This is a large area of 8 m mussel ropes suspended from float lines. Two other unnamed sites lie within this production area, one of which consisted of an area of rope grown mussels suspended from float lines, and the other consisted of a few marker floats only and is in a fallow state.

A large septic discharge was found at Bunessan, approximately 8km away from the mussel raft. About 80 dwellings of various sizes were counted within a few hundred metres of the shore, mainly on the south shore, some of which had private septic tanks with overflows discharging to the loch. Many did not have visible septic overflows, but there is no mains sewer connection in the area. None of these was in close proximity to the shellfish farms and so the impact is anticipated to be minimal.

Livestock density was relatively low overall, but there were areas with high densities. The highest density of livestock was at Rossal farm, on the south eastern corner of the loch. Sheep were present in fields adjacent to the Loch Scridain West: Knockan site.

Many watercourses discharge into the loch, and these had low to moderate levels of *E. coli*. The surrounding land that they drain is a mixture of forest, moorland and pasture. Higher levels of *E. coli* were generally found in streams discharging to the south shore and the head of the loch.

Seawater samples taken from the shore gave results ranging from 0 to 1800 *E. coli* cfu/100ml. Of the seawater samples taken, the highest levels were found in samples taken at the head of the loch, where salinity was very low, and generally the higher results were from samples with lowest salinity. The exception to this was a water sample taken from Bunessan Bay, near the communal septic outflow, which had both high salinity and *E. coli* level. All samples taken from the boat in open water near the mussel farms had relatively low levels of *E. coli* (<10cfu/100ml), which would usually be associated with Class A or Class B waters.

The area is frequented by tourists and there are a few holiday homes and hotels, so it is likely that the population increases significantly during the summer months. Livestock numbers will also be higher in the summer months.

Boat traffic appeared to be minimal with only the occasional mussel boat, yacht, fishing vessel or small dinghy using the loch.

A total of 7 seals were observed in the rocky bay where the Loch Scridain West: Knockan site is located. Aside from that, no significant concentrations of wildlife were seen.

A map is providided in Figure 15.1 that shows the relative locations of the most significant findings of the shoreline survey. Where bacterial concentrations are labelled, 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 this case it would be written as 1E+3.

In summary, identified sources of potentially significant contamination are:

- Light to moderately contaminated freshwater inputs.
- Inputs from livestock grazing on the shoreline
- A few private septic tanks discharging into the loch.
- Possibly Bunessan village, but this is 7 km away from the nearest mussel site.

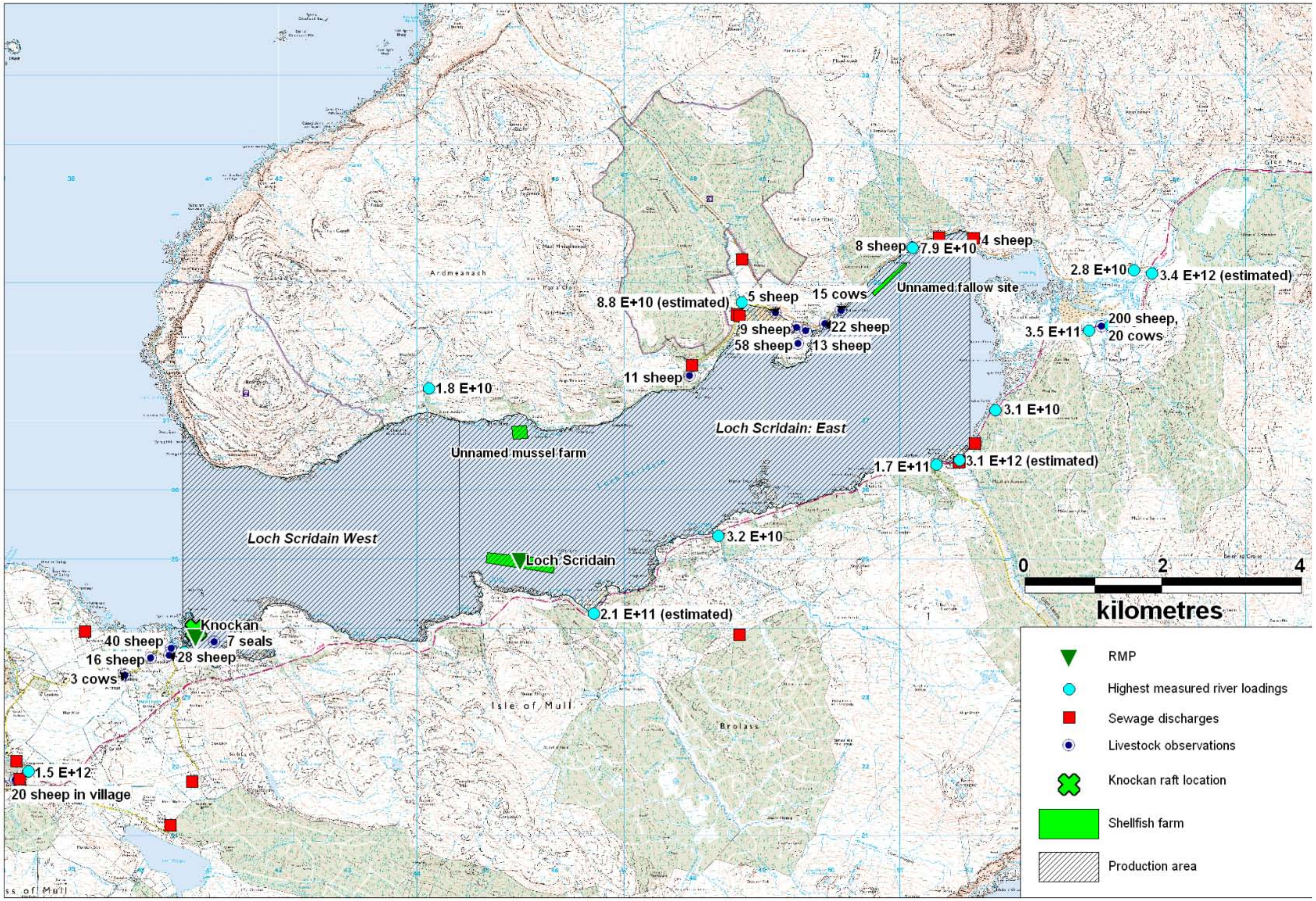


Figure 15.1 Summary of shoreline observations

16. Overall Assessment

Human sewage inputs

With a neighbouring human population at the last census of 185 and with Loch Scridain covering an area of 28.5 km^2, the overall loading of sewage to Loch Scridain is very low. The area is not connected to mains sewerage. A communal discharge at Bunessan appeared to have an effect on the water quality in Bunessan Bay, but is not believed to significantly impact on the shellfisheries, the nearest of which is 7 km away by sea. A number of small private discharges direct to the production areas were found during the course of the shoreline survey, but none of these were close enough to the shellfisheries have significant impacts.

Agricultural inputs

There is no arable agriculture in the vicinity of the loch. There was some grazing of sheep and cattle that would be a significant source of contamination in some parts of the loch. The most concentrated area of grazing was on the southeastern corner of the loch at Rossal Farm, where both cattle and sheep were present. Also of potential significance in this area, there is an expanse of 'salt flat' type grassland, which had large amounts of recent sheep droppings, parts of which may be covered on larger tides. Livestock were also observed on pasture and on the shoreline in other patches around the loch, one to the southwest of the production area, and one around the northeast of the production area.

In conclusion, the most significant aggregation of livestock was in the vicinity of Rossal farm, but this is a significant distance from the mussel farms. Contamination arising from here and other areas of grazing may raise overall levels of contamination within the deeper, better mixed areas of the loch where the mussel farms are located. However, this input will be considered to be spatially diffuse and will not materially affect the location of sampling points.

Wildlife inputs

Wildlife such as seals, cetaceans, waterbirds, deer and otter are likely to be resident in or visit the area, but not in large numbers. Overall, wildlife impacts to the fisheries at Loch Scridain are likely to be localized, minor and unpredictable and will therefore not be explicitly taken into account in determining the sampling plan, although impacts from wildlife may sometimes contribute to the bacterial contamination of shellfish.

Seasonal variation

Historical monitoring results were higher in the summer and autumn compared to the winter. Livestock numbers in the area as a whole are likely to be at their highest during the summer months when lambs and calves are present. During the warmer months livestock may access streams to drink and cool off more frequently, leading to higher levels of faecal contamination in theses streams.

The Isle of Mull as a whole is a popular tourist destination and there are 6-7car ferry sailings every day during the summer season to the island from Oban. There are a few hotels, and a number of small dwellings and trailer homes along the south shore many of which are likely to be holiday homes. On the north shore there is some holiday accommodation at the Tavool estate. Large numbers of tourists pass along the road on the south side of the loch on coach tours to Iona, but generally do not stop. Overall, there are likely to be a significant increase in population during the summer months, but population will remain at a relatively low density nevertheless.

Rivers and Streams

The catchment area for Loch Scridain is 175 km^2, which is relatively small given the area of the loch itself is 28.5 km^2. Many streams and small rivers discharge all around the loch. *E. coli* concentrations measured during the shoreline survey ranged from low to moderate.

The cumulative effect of these watercourses will significantly influence *E. coli* levels in Loch Scridain. The head of the loch, which is shallow and receives a large proportion of the freshwater inputs will be most heavily influenced by freshwater inputs, as demonstrated by the low salinity of water samples taken near the head of the loch during the shoreline survey. Nearer the mouth of the loch, where the shellfish farms are located, the freshwater influence will be much lower. Contamination is likely to be higher where the water is fresher. A stronger freshwater influence may be expected around the fallow Crown Estates lease near the head of the loch, and so mussels grown here may be more heavily contaminated than those grown on the other sites although this could not be confirmed on the shoreline survey.

The Beach River, which discharges near the Loch Scridain East: Loch Scridain site, is likely to have an impact on water quality around the shellfish farm as it empties into the loch less than 0.5 km away. This will materially influence the location of a monitoring point.

Hydrology, meteorology and movement of contaminants

Rainfall patterns at Gruline (the nearest rainfall station) show rainfall is highest from September through to January. An increase in rainfall in September after the drier summer months may be expected to wash a flush of bacteria from the surrounding land into the production area. However, no correlation between rainfall in the previous 2 days and historic monitoring results was found, and the only relationship detected between results and rainfall in the previous 7 days was that results were significantly lower for rainfall quartile 1 compared to quartile 2, and when the production areas were considered separately, the relationship was only found for Loch Scridain West. It may be that the location of the shellfish in deeper water offshore limits the effects of rainfall / runoff borne contamination.

A correlation was found between wind direction and *E. coli* result with lower bacterial concentrations coinciding with periods of southeasterly winds, although the reason for this is unclear as a south easterly wind may be expected to move contamination from sources on the shore towards the mussel sites. Conversely, it may be that the sites are simply more sheltered from south easterly winds, and so there is less circulation of contamination around the loch, but if this were the case, the same might be expected to apply to south westerly winds.

Given the large size of the loch, the potential for dilution of contaminants is high. Freshwater influence is relatively low, but flushing time is quite high. The available tidal information suggests that movement of contaminants within the loch is likely to be predominantly wind driven, with contaminating sources nearest the mussel farms most likely to have a significant local impact. The farm at Knockan lies within a sheltered bay and is likely to be impacted by any runoff occuring within that bay. The larger farm along the south shore at Loch Scridain will be more significantly impacted by faecal contaminants carried to the loch via the Beach River.

Analysis of results

Historic shellfish hygiene monitoring results are available from 1999 to present, with samples collected from three reported locations, two on the Loch Scridain East: Loch Scridain site (200 m apart) and one on the small mussel raft at the Loch Scridain West: Knockan site. No significant difference between the average of results obtained from these three locations was found, and no overall trend in microbiological quality was seen during this period. Highest peak results were obtained at Loch Scridain East.

SEPA have reported shellfish growing waters monitoring results from 2002 onward. Shore mussel samples tested for faecal coliforms gave a higher geometric mean result than the geometric mean *E. coli* result from the FSAS monitoring programme. It might be expected that higher levels of contamination are found at this sampling location compared to rope mussels grown offshore, as a large watercourse enters the loch here, livestock have access to the shoreline and there is some human habitation.

Seawater samples taken from the shore gave results ranging from 0 to 1800 *E. coli* cfu/100ml. Of the seawater samples taken, the highest levels were found in samples taken at the head of the loch, where salinity was very low, and generally the higher results were from samples with lowest salinity. All samples taken from the boat in open water near the mussel farms had less than 10 *E. coli* cfu/100ml.

Levels of contamination and calculated bacterial loadings for streams discharging into the production area were fairly low relative to the size of the loch. As noted in the previous paragraph, highest results were found at lower salinities so it is likely that these inputs are responsible for carrying most of the contamination into the production area.

Of the six mussel samples taken from Loch Scridain East: Loch Scridain on the shoreline survey a consistent pattern emerged in that the samples taken from the top of the ropes were more heavily contaminated (310, 310 and 500 mpn/100g) than those taken from lower in the water column (<20, 20 and <20 mpn/100g). This is probably due to the presence of a layer of less dense fresher water at the surface, and implies that the RMP should be set at a depth of <1 m. A similar pattern was not observed at the Loch Scridain West: Knockan site, but only two samples were taken from here.

Summary

Factors of relevance to the sampling plan are as follows:

- Seasonality and variability of historic monitoring results, diffuse agricultural inputs and seasonal fluctuations in population levels would suggest monthly monitoring is appropriate.
- Higher levels of contamination are associated with fresh water, and so areas of lower salinity at the head of the loch should be excluded from the production area as they will be more likely to be contaminated.
- As there was no difference in mean historic monitoring results between sites despite the large and comprehensive dataset, amalgamation of the two production areas may be suggested.
- Loch Scridain West has a slightly lower overall geometric mean historic *E. coli* monitoring result, and has held a more favourable classification than Loch Scridain East in two of the three years since the areas were separated, and so amalgamating the areas may slightly disadvantage Loch Scridain West.
- Higher results were found in shellfish taken from the top of the water column, so the RMP should be set at the top of the water column to reflect this.
- For Loch Scridain East, the nearest contaminating source is the Beach River and so the RMP should be set to capture contamination flowing from the river outlet to the site.
- For Loch Scridain West, the raft is too small for any geographical effects to be taken into consideration when setting the RMP.

Other factors considered in this report have no material affect on the proposed sampling plan for reasons already discussed.

17. Recommendations

The current production area boundaries are given as the area bounded by lines drawn between NM 4460 2700 to NM 4460 2419 and between NM 5200 2969 to NM 5200 2663 (Loch Scridain East), and the area bounded by lines drawn between NM 4060 2697 to NM 4060 2368 and between NM 4460 2700 to NM 4460 2419 (Loch Scridain West).

It is recommended that the fallow site near the head of the loch be excluded from the new production area boundaries due to the likely increased fresh water influence here. Should this site come back into production, a separate production area would be recommended for it. The recommended Loch Scridain East production area is the area bounded by lines drawn between NM 4507 2700 and NM 4477 2478 and between NM 4618 2690 and NM 4618 2448. It is recommended that the RMP is set at NM 4597 2489, at the closest point to the nearest major freshwater input (Beach River). Sampling depth is recommended to be 1 metre due to concentration of contaminants in the fresh water layer near the surface and with a sampling tolerance of 20 m to allow for movement of lines.

The recommended revised Loch Scridain West production area is the area bounded by lines drawn between NM 4060 2691 and NM 4060 2368 and between NM 4154 2636 and NM 4150 2404. It is recommended that the RMP be set at NM 4079 2399, with a tolerance of 20 m. Sampling depth is recommended to be 1 m due to concentration of contaminants in the fresh water layer near the surface.

It is recommended that monthly sampling be maintained for this production area because of the seasonal changes in levels of contamination.

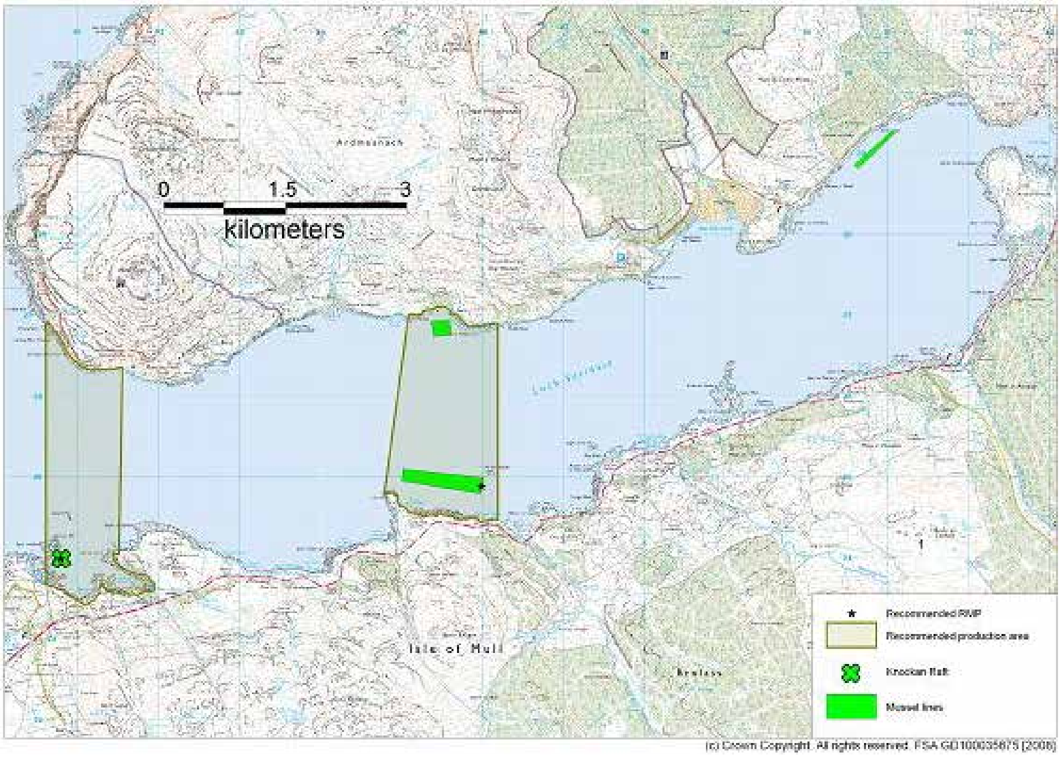


Figure 17.1 Map of recommendations for Loch Scridain

18. References

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19. List and Figures

Appendices

1. Shoreline Survey Report
2. Sampling plan
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4. Statistical Data
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Appendix 1

Shoreline Survey Report

Loch Scridain
AB314 and AB315

Scottish Sanitary Survey Project

Cefas

Shoreline Survey Report

Prod. area: Loch Scridain East (AB314) and Loch Scridain West (AB315)
Site name: Loch Sridain East: Loch Scridain (AB31405408) and Loch Scridain West: Knockan (AB31505308)
Species: Common Mussel
Harvester: Celtic Sea Ltd (Loch Scridain East), Mr Nigel Burgess (Loch Scridain West)
Local Authority: Argyll and Bute Council
Status: Existing site
Date Surveyed: 4-6 September 2007
Surveyed by: Christine Mclachlan and Alastair Cook
Existing RMPs: NM455250 and NM408239
Area Surveyed: See map (Figures 1-3).

Weather observations

4/9/07 - wet, calm.
5/9/07 - wet, light SW winds.
6/9/07 - dry, light SW winds.
26/11/07 - fresh westerly wind, frequent showers.

Site Observations

Specific observations taken on site are mapped in Figures 1-3 and listed in Table 3. Water and shellfish samples were collected at sites marked on Figures 4, 5 and 6 (maps of freshwater and seawater samples are presented separately for clarity). Bacteriology results are presented in Tables 4 and 5. Photographs referenced in Table 3 and the body of the report are presented in Figures 7-25.

Fishery

Loch Scridain East: Loch Scridain is a large mussel farm, where mussels are grown on ropes suspended from float lines (Figure 5 and cover photograph). The site is 3 float lines long, and 6 to 8 float lines wide. A variety of sizes were present from empty ropes to harvestable mussels. The growing ropes were approximately 8m long. The farm required some maintenance work at the time of survey. Six mussel samples were taken from the Loch Sridain East: Loch Scridain site.

Loch Scridain West: Knockan consists of a single raft with an estimated size of 12mx12m from which growing ropes are suspended (Figure 8). The ropes examined were approximately 4m long, and had mussels of different sizes attached, including some that were larger than the typical harvesting size. The location of the raft cannot be easily seen on the maps when drawn to scale due to its small size, but is approximately 90m north of the RMP. At the Loch Scridain West: Knockan site only 2 samples were taken.

Two other mussel growing areas were noted during the course of the survey. In the North East end of the Loch, a single float line was observed (Figure 25). The floats were spaced too widely to support any mussel ropes underneath, and it is reported that this farm is currently in a 'fallow state'. A second area of float lines was observed close to the North shore, approximately opposite to the

Loch Sridain East: Loch Scridain site (Figure 24). This consisted of 7 lines of floats. Some of the float lines were quite low in the water, suggesting the farm has been established for some time, and a heavy growth of mussels was present. Both these two sites fall within the Loch Scridain East production area and are owned by Celtic Seas Ltd.

Sewage/Faecal Sources

There are no Scottish Water discharges directly to the loch. A large communal septic tank, presumably serving the majority of the approximately 50 dwellings in the village of Bunessan, lies approximately 7 km by sea from the production site at Knockan (Figure 9). From Bunessan round the loch to Tavool house on the north shore, a total of around 80 dwellings of various sizes were counted within a few hundred metres of the shoreline, mainly on the south shore. Several smaller private septic tanks with overflows to the Loch were seen serving one or a few houses (Figures 14, 15 & 20). Not all houses near the shoreline had visible septic overflows to the Loch, but there is no mains sewer connection in this area.

A total of ~440 sheep and ~40 cows were noted during the shoreline survey indicating a relatively low density of livestock. These were mainly on the south shore on patches of pasture. The highest concentration of livestock was at Rossal farm, at the head of the loch on the south shore, where ~200 sheep and ~20 cattle were observed on an area of fenced pasture surrounding the farm house (Figure 17). There was also an area of salt flat type grassland on the shore of the loch here, and although there were no livestock present at the time of survey, there was plenty of evidence to suggest the area had recently been used for grazing. Sheep were present in fields adjacent to the Loch Scridain West: Knockan site, and there was evidence of sheep having recently been on the shore here. Small numbers of livestock were observed actually on the shoreline in a few other areas (e.g. Figure 22). It is likely that some livestock was not seen due to the topography, trees and poor visibility at times.

Several rivers discharge into the Loch, as well as many smaller watercourses. The surrounding land that these drain is a mixture of forest, moorland and pasture. Water samples were taken and discharge estimated from the rivers and from some of the smaller watercourses. Table 1 and 2 presents the estimated discharge and bacterial loading as measured during the shoreline survey from watercourses with a discharge of more than 0.5 m^3/sec. As the flow was only estimated on some watercourses, they were remeasured using a flow meter in November 2007.

Table 1. Discharge and bacterial loading of larger watercourses (September 2007)

River name	Position sampled	Discharge (m^3/sec)	*E. coli* / 100ml	Photograph
Bunessan River	NM 38374 21928	0.92	1900	Figure 9
Leidle River	NM 51853 26434	1.25*	2900	Figure 12
Beach River	NM 46556 24215	2.40*	100	Figure 14
Abhainn nan Torr	NM 48359 25333	0.75	<100	
Allt Fhearchair	NM 53723 28310	0.58	700	
An Leth allt	NM 54034 28386	0.93	200	
Allt a Mhaim	NM 54374 28447	1.34	300	
Coladoir River	NM 54633 29133	7.50*	500	Figure 16
Allt a Ghlinne Dhuibh	NM 54377 29185	0.64	<100	
Allt na Coille Moire	NM 51173 29509	0.91	100	
Abhainn Bail a Mhuillinn	NM 48698 28714	2.04*	<100	Figure 19
Abhainn Buel-ath an Tairbh	NM 44168 27477	0.96	22	Figure 22

*Estimate only so remeasured in November

Table 2. Discharge and bacterial loading of larger watercourses (November 2007)

River name	Position sampled	Discharge (m^3/sec)	*E. coli* / 100ml	Photograph
Leidle River	NM 51877 26426	0.82	100	Figure 12
Beach River	NM 46535 24219	0.77	<100	Figure 14
Coladoir River	NM 54654 29142	*	<100	Figure 16
Abhainn Bail a Mhuillinn	NM 48723 28706	0.40	<100	Figure 19

* Not possible to measure safely using available equipment due to size and depth

Overall, higher loadings were generally found in watercourses discharging to the south shore and to the head of the loch. Levels of contamination were lower when the selected watercourses were resampled in November.

A total of 18 seawater samples were collected during the survey. Highest levels of *E. coli* were found in the two samples taken at the head of the loch. Salinity here was very low. This area is also close to Rossal farm, and adjacent to an area of salt flat grassland which had recently been used for grazing.

Seasonal Population

The Isle of Mull as a whole is a popular tourist destination and there are several car ferry sailings every day to the island from Oban. There are a handful of hotels, and a number of small dwellings and trailer homes along the south shore many of which are likely to be holiday homes. On the north shore there is some holiday accommodation at the Tavool estate. A few cyclists, hikers and birdwatchers were seen around the loch during the course of the survey. Large number of tourists pass along the road on the south side of the loch on coach tours to Iona, but generally do not stop. Overall, there are likely to be a significant increase in population during the summer months.

Boats/Shipping

One jetty observed was just outside Bunessan, outside of the Loch and the production areas. It was in active use, with one fishing boat moored there and a small yacht moored to a buoy just offshore from the jetty. Two other smaller jettys were seen, one located by the processing shed serving the Loch Scridain East: Loch Scridain mussel site and the other on the north shore by Killiemore house. A total of 4 small dinghies were seen moored in the Loch. A ferry service operates from Fionnphort (about 15 km by sea from the production area) to Iona, sailing several times a day year round and catering primarily for foot passengers. Overall boat traffic in the loch appeared to be minimal with the occasional mussel boat, yacht, fishing vessel or small dinghy using the loch and the majority of these non-residential.

Land Use

The land surrounding Loch Scridain is predominantly rough, slightly boggy moorland, with areas of woodland and pasture. Livestock droppings were seen on some moorland areas, but generally livestock was only seen on areas of pasture at the time of survey.

Wildlife/Birds

A total of 7 seals were observed in the rocky bay (4 from the boat, 3 from the shore) where the Knockan site is located (Figure 12). Otters were seen at two different locations around the loch. No significant concentrations of birdlife were seen.

General observations

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 were measured at the most convenient point of access and not necessarily at the point at which the watercourses enter the loch.

Summary

Identified sources of potentially significant faecal contamination were:

- Light to moderately contaminated freshwater inputs.
- Inputs from livestock grazing on or near the shoreline.
- A few private septic tanks discharging directly into the loch.
- Bunessan village.

Inputs from both humans and livestock are likely to be higher during the summer months.

Figure 1. Map of Shoreline Observations

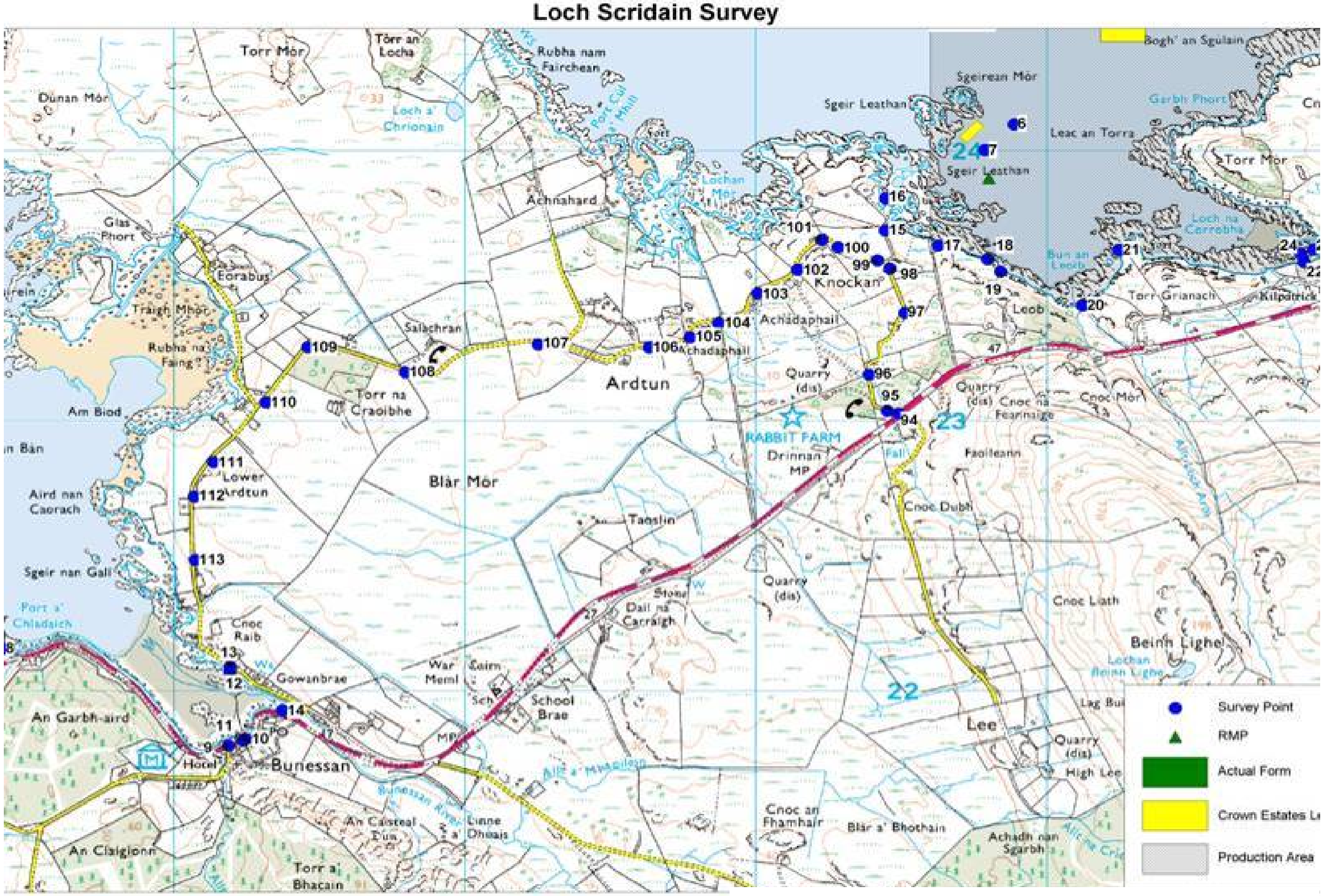


Figure 2. Map of Shoreline Observations

Figure 3. Map of shoreline observations

Table 3. Shoreline Observations

Number	Date	Position	East	North	Photograph	Description
1	04-Sep-07	NM 45009 25097	145009	725097	Figure 7	Corner of lines. No mussels on this rope, Water sample 1
2	04-Sep-07	NM 44995 24950	144995	724950		Corner of lines. Water sample 2. Mussels sample 1 (top 2m) and mussel sample 2 (bottom).
3	04-Sep-07	NM 45998 24993	145998	724993		Corner of lines. Water sample 3. Mussel sample 3 (top). Mussel sample 4 (middle). Mussel sample 5 (bottom).
4	04-Sep-07	NM 45969 24794	145969	724794		Corner of lines. Water sample 4.
5	04-Sep-07	NM 46018 24825	146018	724825		Mussel sample 6 (top) taken as close to corner as possible. Lines too heavy to lift so could not get samples from lower down.
6	04-Sep-07	NM 40887 24099	140887	724099		3 or 4 seals on rock.
7	04-Sep-07	NM 40787 24003	140787	724003	Figure 8	Small mussel raft (~15mx15m). Lines only 4m long. Water sample 5. Mussel sample 7 (top). Mussel sample 8 (bottom).
8	04-Sep-07	NM 37413 22156	137413	722156		Fishing pier. 2 boats. 1 caravan.
9	04-Sep-07	NM 38189 21798	138189	721798		Bunessan village. ~50 houses, 1 pub, 3 shops, school, church & restaurant. ~20 sheep wandering around village.
10	04-Sep-07	NM 38239 21818	138239	721818	Figure 9	Communal septic tank. Pipe leading out to marker about 100m offshore.
11	04-Sep-07	NM 38245 21823	138245	721823		Water sample 6.
12	04-Sep-07	NM 38193 22072	138193	722072	Figure 10	2x 15cm sewer pipes encased in concrete, trickle coming out of end.
13	04-Sep-07	NM 38194 22089	138194	722089		Sheep droppings on roadside, shoreline not fenced off here.
14	04-Sep-07	NM 38374 21928	138374	721928	Figure 11	Stream 440cmx21cmx1m/s. Water sample 7 (fresh).
15	04-Sep-07	NM 40444 23705	140444	723705		40 sheep in field.
16	04-Sep-07	NM 40445 23825	140445	723825		Water sample 8. Sheep droppings on shoreline.
17	04-Sep-07	NM 40626 23650	140626	723650		Stream 34cmx16cmx1.2m/s. Water sample 9 (fresh).
18	04-Sep-07	NM 40796 23599	140796	723599	Figure 12	3 seals in water.
19	04-Sep-07	NM 40841 23553	140841	723553		Very small stream not sampled.
20	04-Sep-07	NM 41121 23428	141121	723428		Stream 150cmx14cmx0.64m/s. Water sample 10 (fresh).
21	04-Sep-07	NM 41247 23633	141247	723633		Water sample 11.
22	05-Sep-07	NM 41882 23589	141882	723589		Cow pat.
23	05-Sep-07	NM 41915 23635	141915	723635	Figure 13	Stream 320cmx11cmx0.33m/s. Water sample 12 (fresh).

24	05-Sep-07	NM 41872 23621	141872	723621		Water sample 13.
25	05-Sep-07	NM 51518 26367	151518	726367		Stream 270cmx11cmx0.85m/s. Water sample 14 (fresh).
26	05-Sep-07	NM 51497 26397	151497	726397		Water sample 15.
27	05-Sep-07	NM 51565 26376	151565	726376		2 houses. Cowpat on shore.
28	05-Sep-07	NM 51644 26381	151644	726381		Bed & Breakfast.
29	05-Sep-07	NM 51690 26369	151690	726369		Very small stream not sampled.
30	05-Sep-07	NM 51782 26384	151782	726384		3 houses and village hall.
31	05-Sep-07	NM 51840 26401	151840	726401	Figure 14	Septic tank to 15cm pipe discharging in river mouth. Dribble coming out.
32	05-Sep-07	NM 51853 26434	151853	726434		River (too large to measure, estimated flow 1-1.5 cumecs). Water sample 16 (freshwater) taken downstream from pipe (31).
33	05-Sep-07	NM 52069 26677	152069	726677	Figure 15	Septic tank with overflow to beach, not flowing. 3 houses and 1 hotel served by it.
34	05-Sep-07	NM 52139 26781	152139	726781		Stream 100cmx5cmx0.6m/s. Not sampled.
35	05-Sep-07	NM 52239 26968	152239	726968		Very small stream not sampled.
36	05-Sep-07	NM 52371 27158	152371	727158		Stream 200cmx15cmx0.59m/s. Water sample 17 (fresh).
37	05-Sep-07	NM 52610 27420	152610	727420		Stream 100cmx20cmx1m/s. Not sampled.
38	05-Sep-07	NM 52638 27444	152638	727444		1 house.
39	05-Sep-07	NM 53004 27927	153004	727927		2 houses here, 3 more out on spit.
40	05-Sep-07	NM 53451 28458	153451	728458		Water sample 18.
41	05-Sep-07	NM 44564 24162	144564	724162		Water sample 19.
42	05-Sep-07	NM 44869 24195	144869	724195		Stream 165cmx9cmx0.8m/s. Water sample 20.
43	05-Sep-07	NM 44965 24248	144965	724248		Very small stream not sampled.
44	05-Sep-07	NM 44975 24643	144975	724643		1 otter, not sampled.
45	05-Sep-07	NM 45318 24480	145318	724480		Shellfish shed and jetty.
46	05-Sep-07	NM 45305 24522	145305	724522		Water sample 21.
47	05-Sep-07	NM 46517 24187	146517	724187		Holiday cottage.
48	05-Sep-07	NM 46556 24215	146556	724215	Figure 16	River (too large to measure, estimated flow 2 cumecs). Estimated size 1500cmx20cmx0.8m/s. Water sample 22 (fresh).
49	05-Sep-07	NM 46720 24398	146720	724398		House.
50	05-Sep-07	NM 46768 24489	146768	724489		Water sample 23.

51	05-Sep-07	NM 47461 24724	147461	724724		Stream 190cmx10cmx0.33m/s. Water sample 24 (fresh).
52	05-Sep-07	NM 47413 24707	147413	724707		Water sample 25.
53	05-Sep-07	NM 48359 25333	148359	725333		Stream 250cmx20cmx1.5m/s. Water sample 26 (fresh).
54	05-Sep-07	NM 53821 28376	153821	728376		Salt flats with sheep droppings on.
55	05-Sep-07	NM 53723 28310	153723	728310		Stream 270cmx18cmx1.2m/s. Water sample 27 (fresh).
56	05-Sep-07	NM 53913 28366	153913	728366	Figure 17	Farmhouse, cottage and 3 barns. About 200 sheep and 20 cows in surrounding fields.
57	05-Sep-07	NM 54034 28386	154034	728386		Stream 430cmx18cmx1m/s. Water sample 28 (fresh).
58	05-Sep-07	NM 54374 28447	154374	728447		Stream 450cmx27cmx1.1m/s. Water sample 29 (fresh).
59	05-Sep-07	NM 54633 29133	154633	729133	Figure 18	River (too large to measure, flow estimated at 5-10 cumecs). Water sample 30 (fresh).
60	06-Sep-07	NM 54377 29185	154377	729185		Stream 460cmx14cmx1m/s. Water sample 31 (fresh).
61	06-Sep-07	NM 53325 29007	153325	729007	Figure 19	Water sample 32. 3 houses and 2 boats on opposite side, Some animal droppings. Brown scum on water.
62	06-Sep-07	NM 51941 29730	151941	729730		Stream 165cmx3cmx1m/s. Water sample 33 (fresh).
63	06-Sep-07	NM 52042 29677	152042	729677		Stream 130cmx4cmx0.8m/s. House.
64	06-Sep-07	NM 52070 29638	152070	729638		Stream 190cmx11cmx0.6m/s. 4 sheep.
65	06-Sep-07	NM 52051 29651	152051	729651		Inspection cover on beach adjacent to house. Pipe not visible (must be buried). Presumably associated with septic system from house. Cattle and sheep dung on beach.
66	06-Sep-07	NM 51552 29655	151552	729655	Figure 20	House, septic tank with overflow to beach (not flowing).
67	06-Sep-07	NM 51173 29509	151173	729509	Figure 21	River 730cmx25cmx0.5m/s. Water sample 34 (fresh). 8 sheep on beach.
68	06-Sep-07	NM 50139 28600	150139	728600		15 cows in field.
69	06-Sep-07	NM 49909 28403	149909	728403		22 sheep in field.
70	06-Sep-07	NM 49811 28346	149811	728346		Farmhouse. Jetty with 2 small boats.
71	06-Sep-07	NM 49661 28392	149661	728392		2 houses.
72	06-Sep-07	NM 49629 28297	149629	728297		Field of 13 sheep.
73	06-Sep-07	NM 49520 28118	149520	728118		Field of 58 sheep.
74	06-Sep-07	NM 49499 28346	149499	728346		Field of 9 sheep.
75	06-Sep-07	NM 49419 28383	149419	728383		2 small houses.

76	06-Sep-07	NM 49370 28436	149370	728436		Stream 90cmx3cmx0.3m/s. Not sampled.
77	06-Sep-07	NM 49233 28537	149233	728537		Very small stream not sampled. Dung on beach.
78	06-Sep-07	NM 49198 28557	149198	728557	Figure 22	House. 5 sheep on beach. Very small stream.
79	06-Sep-07	NM 49066 28573	149066	728573		Water sample 35.
80	06-Sep-07	NM 48698 28714	148698	728714		River 17mx30cmx0.4m/s. (Flow estimated visually at 2 cumecs). Water sample 36 (fresh).
81	06-Sep-07	NM 48644 28522	148644	728522		House.
82	06-Sep-07	NM 48401 28082	148401	728082		House.
83	06-Sep-07	NM 48021 27910	148021	727910		Large house plus cottages.
84	06-Sep-07	NM 47953 27652	147953	727652		Field of 11 sheep.
88	06-Sep-07	NM 46121 27328	146121	727328	Figure 23	Photo of mussel lines taken from here.
89	06-Sep-07	NM 45286 27415	145286	727415		Photo of mussel lines taken from here.
90	06-Sep-07	NM 44168 27477	144168	727477	Figure 24	River 8mx12cmx1m/s. Water sample 37 (fresh).
91	06-Sep-07	NM 46983 27433	146983	727433		3 chalets.
92	06-Sep-07	NM 50490 28984	150490	728984	Figure 25	Mussel site under construction. Photo taken from here.
93	06-Sep-07	NM 50737 29233	150737	729233		Water sample 38.
94	06-Sep-07	NM 40491 23028	140491	723028		House.
95	06-Sep-07	NM 40451 23038	140451	723038		House.
96	06-Sep-07	NM 40389 23171	140389	723171		Trailer home and House.
97	06-Sep-07	NM 40511 23400	140511	723400		Trailer home.
98	06-Sep-07	NM 40461 23565	140461	723565		House.
99	06-Sep-07	NM 40418 23595	140418	723595		2 trailer homes and 1 house. Field with 28 sheep.
100	06-Sep-07	NM 40282 23643	140282	723643		Trailer home.
101	06-Sep-07	NM 40226 23671	140226	723671		House.
102	06-Sep-07	NM 40143 23560	140143	723560		2 caravans, 1 house, field of 16 sheep.
103	06-Sep-07	NM 40006 23472	140006	723472		Trailer home.
104	06-Sep-07	NM 39872 23363	139872	723363		4 houses, 1 trailer home.
105	06-Sep-07	NM 39774 23310	139774	723310		3 cows.
106	06-Sep-07	NM 39633 23273	139633	723273		3 houses.
107	06-Sep-07	NM 39252 23284	139252	723284		4 houses down by shore.

108	06-Sep-07	NM 38796 23180	138796	723180		6 houses.
109	06-Sep-07	NM 38460 23274	138460	723274		2 houses.
110	06-Sep-07	NM 38317 23069	138317	723069		4 houses.
111	06-Sep-07	NM 38136 22848	138136	722848		3 houses.
112	06-Sep-07	NM 38070 22720	138070	722720		2 houses.
113	06-Sep-07	NM 38075 22485	138075	722485		3 houses.
114	26-Nov-07	NM 48723 28706	148723	728706		Water sample ScridainNov1. Stream 1588cmx12.5cmx0.205m/s.
115	26-Nov-07	NM 46535 24219	146535	724219		Water sample ScridainNov2. Stream 750cmx27.8cmx0.37m/s
116	26-Nov-07	NM 51877 26426	151877	726426		Water sample ScridainNov3. Stream 528cmx33.3cmx0.485m/s
117	26-Nov-07	NM 54654 29142	154654	729142		Water sample ScridainNov4. Coladoir River. Too large to measure.

Table 4. Water sample results

No.	Date	Sample ID	Type	NGR	E. coli (cfu/100ml)	Salinity (g/L)
1	04/09/2007	Scridian1	Sea	NM 45009 25097	2	31.6
2	04/09/2007	Scridian2	Sea	NM 44995 24950	1	31.8
3	04/09/2007	Scridian3	Sea	NM 45998 24993	1	31.8
4	04/09/2007	Scridian4	Sea	NM 45969 24794	0	33.8
5	04/09/2007	Scridian5	Sea	NM 40787 24003	9	34.3
6	04/09/2007	Scridian6	Sea	NM 38245 21823	600	34.0
7	04/09/2007	Scridian7	Fresh	NM 38374 21928	1900	Not tested
8	04/09/2007	Scridian8	Sea	NM 40445 23825	560	30.7
9	04/09/2007	Scridian9	Fresh	NM 40626 23650	1300	Not tested
10	04/09/2007	Scridian10	Fresh	NM 41121 23428	<100	Not tested
11	04/09/2007	Scridian11	Sea	NM 41247 23633	0	34.3
12	05/09/2007	Scridian12	Fresh	NM 41915 23635	<100	Not tested
13	05/09/2007	Scridian13	Sea	NM 41872 23621	330	1.66
14	05/09/2007	Scridian14	Fresh	NM 51518 26367	800	Not tested
15	05/09/2007	Scridian15	Sea	NM 51497 26397	33	29.8
16	05/09/2007	Scridian16	Fresh	NM 51853 26434	2900	Not tested
17	05/09/2007	Scridian17	Fresh	NM 52610 27420	200	Not tested
18	05/09/2007	Scridian18	Sea	NM 53451 28458	1800	0.1
19	05/09/2007	Scridian19	Sea	NM 44564 24162	0	33.4
20	05/09/2007	Scridian20	Fresh	NM 44869 24195	<100	Not tested
21	05/09/2007	Scridian21	Sea	NM 45305 24522	17	32.2
22	05/09/2007	Scridian22	Fresh	NM 46556 24215	100	Not tested
23	05/09/2007	Scridian23	Sea	NM 46768 24489	84	18.8
24	05/09/2007	Scridian24	Fresh	NM 47461 24724	<100	Not tested
25	05/09/2007	Scridian25	Sea	NM 47413 24707	130	28.1
26	05/09/2007	Scridian26	Fresh	NM 48359 25333	<100	Not tested
27	05/09/2007	Scridian27	Fresh	NM 53723 28310	700	Not tested
28	05/09/2007	Scridian28	Fresh	NM 54034 28386	200	Not tested
29	05/09/2007	Scridian29	Fresh	NM 54374 28447	300	Not tested
30	05/09/2007	Scridian30	Fresh	NM 54633 29133	500	Not tested
31	06/09/2007	Scridian31	Fresh	NM 54377 29185	<100	Not tested
32	06/09/2007	Scirdian32	Sea	NM 53325 29007	700	0.3
33	06/09/2007	Scridian33	Fresh	NM 51941 29730	<100	Not tested
34	06/09/2007	Scridian34	Fresh	NM 51173 29509	100	Not tested
35	06/09/2007	Scridian35	Sea	NM 49066 28573	140	3.9
36	06/09/2007	Scridian36	Fresh	NM 48698 28714	<100	Not tested
37	06/09/2007	Scridian37	Fresh	NM 44168 27477	22	0.02
38	06/09/2007	Scridian38	Sea	NM 50737 29233	10	21.1
39	26/11/2007	ScridainNov1	Fresh	NM 48723 28706	<100	Not tested
40	26/11/2007	ScridainNov2	Fresh	NM 46535 24219	<100	Not tested
41	26/11/2007	ScridainNov3	Fresh	NM 51877 26426	100	Not tested
42	26/11/2007	ScridainNov4	Fresh	NM 54654 29142	<100	Not tested

Table 5. Shellfish Sample Results

No.	Sample ID	Date taken	Type	NGR	E. coli (mpn/100g)	Depth
1	Scridain 1	04/09/2007	Mussel	NM 44995 24950	500	<1m
2	Scridian 2	04/09/2007	Mussel	NM 44995 24950	<20	8m
3	Scridian 3	04/09/2007	Mussel	NM 45998 24993	310	<1m
4	Scridian 4	04/09/2007	Mussel	NM 45998 24993	<20	4m
5	Scridian 5	04/09/2007	Mussel	NM 45998 24993	20	8m
6	Scridian 6	04/09/2007	Mussel	NM 46018 24825	310	<1m
7	Scridian 7	04/09/2007	Mussel	NM 40787 24003	40	<1m
8	Scridian 8	04/09/2007	Mussel	NM 40787 24003	40	4m

Figure 4. Water sample results map (freshwater)

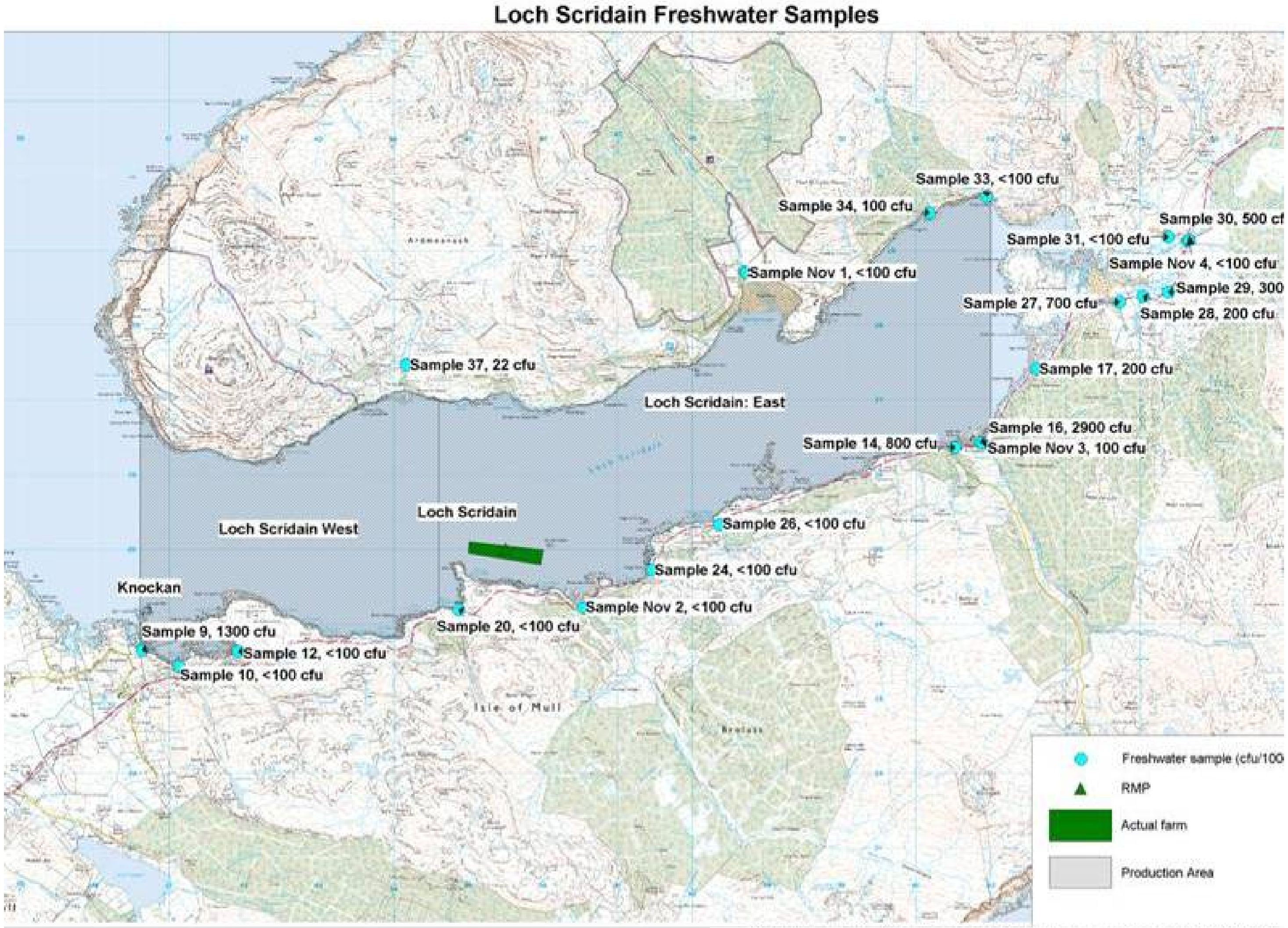


Figure 5. Water sample results map (seawater)

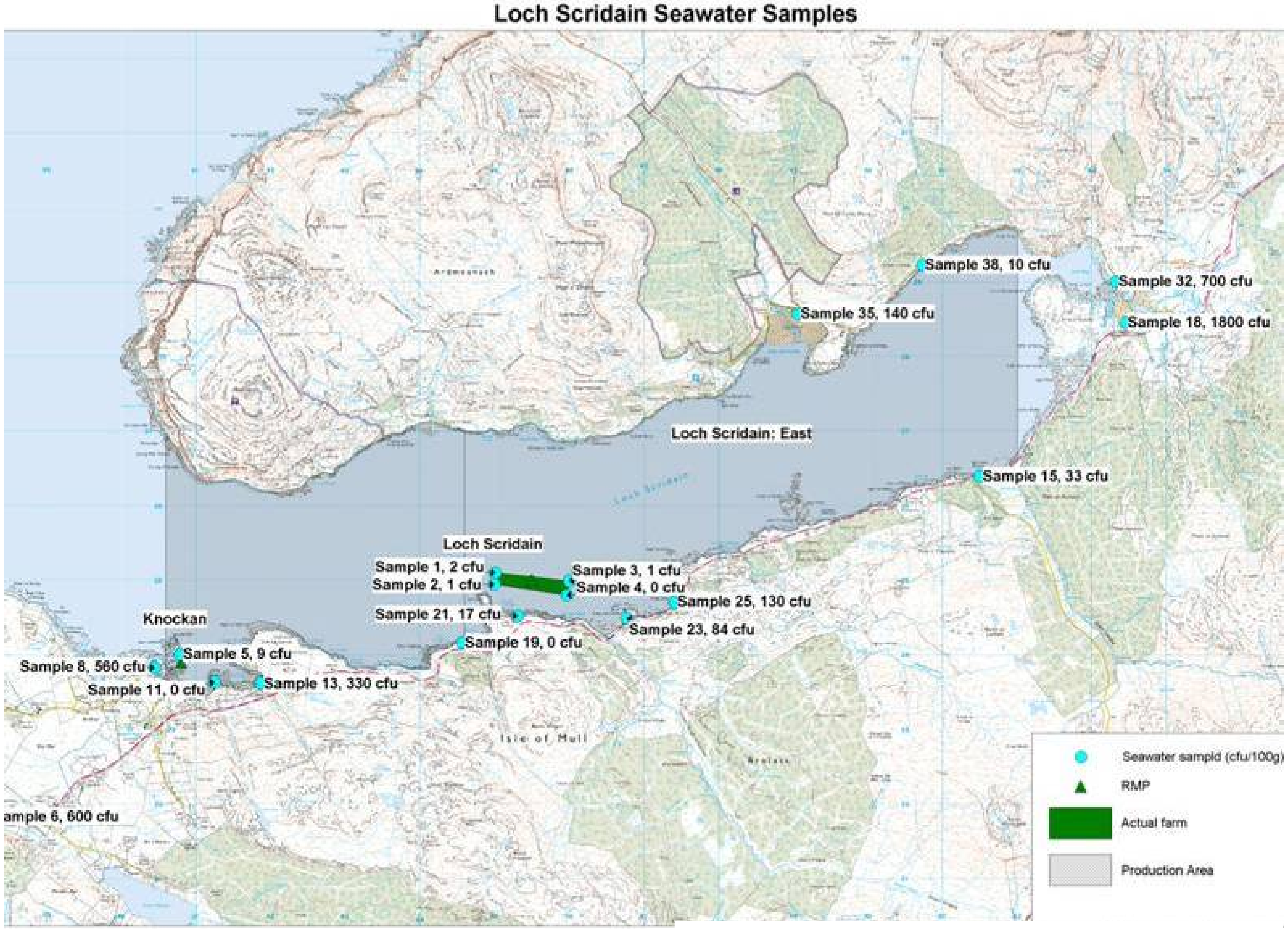


Figure 6. Shellfish sample results map

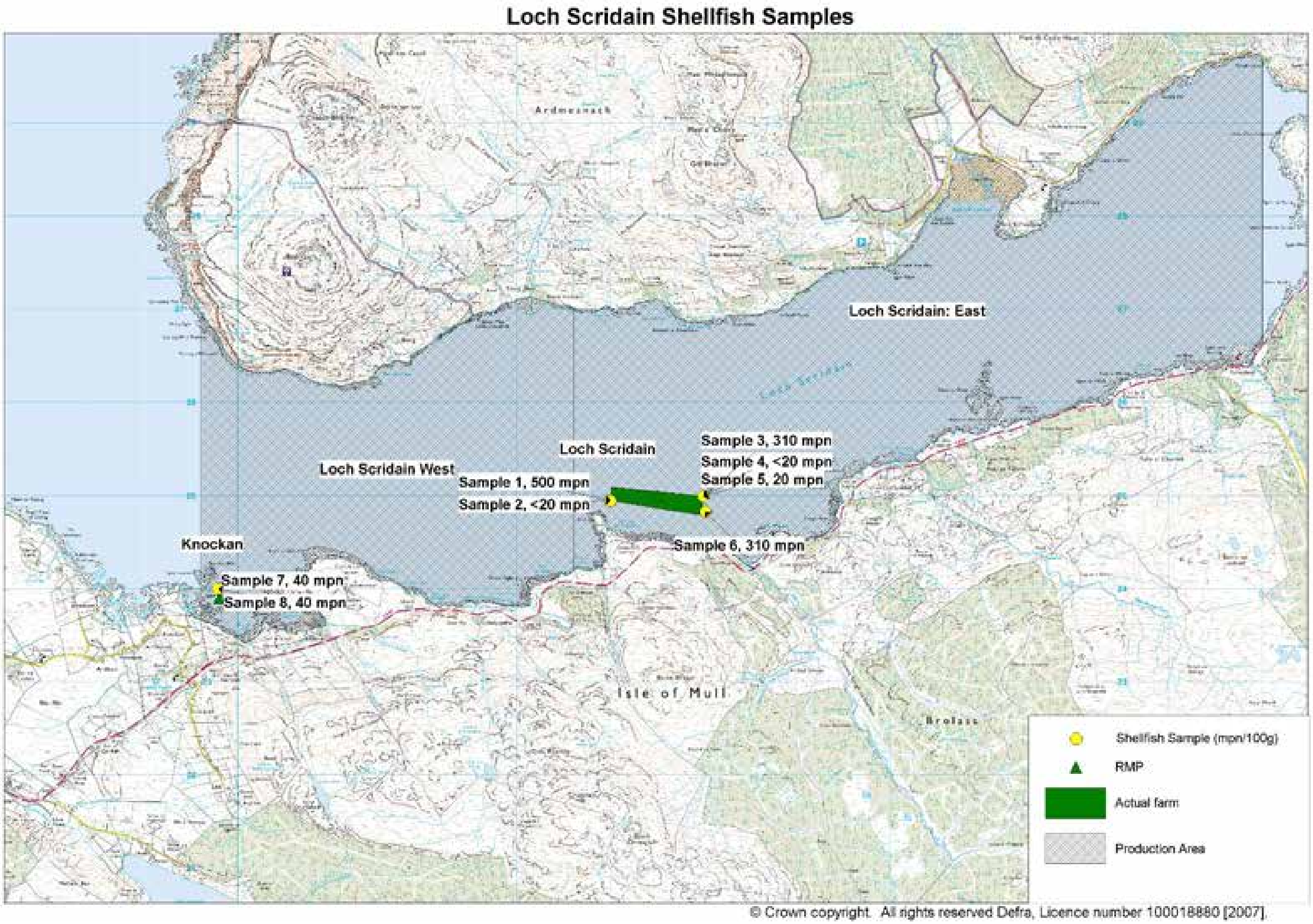


Figure 7. Loch Scridain East: Loch Scridain mussel lines

Figure 8. Loch Scridain West: Knockan mussel raft

Figure 9. Bunessan communal septic tank

Figure 10. Private sewer pipes at Bunessan

Figure 11. Bunessan River

Figure 12. View of rocky bay, seals and Knockan mussel raft

Figure 13. Stream

Figure 14. Septic tank outflow to mouth of Leidle River

Figure 15. Septic tank with overflow to beach

Figure 16. Beach River

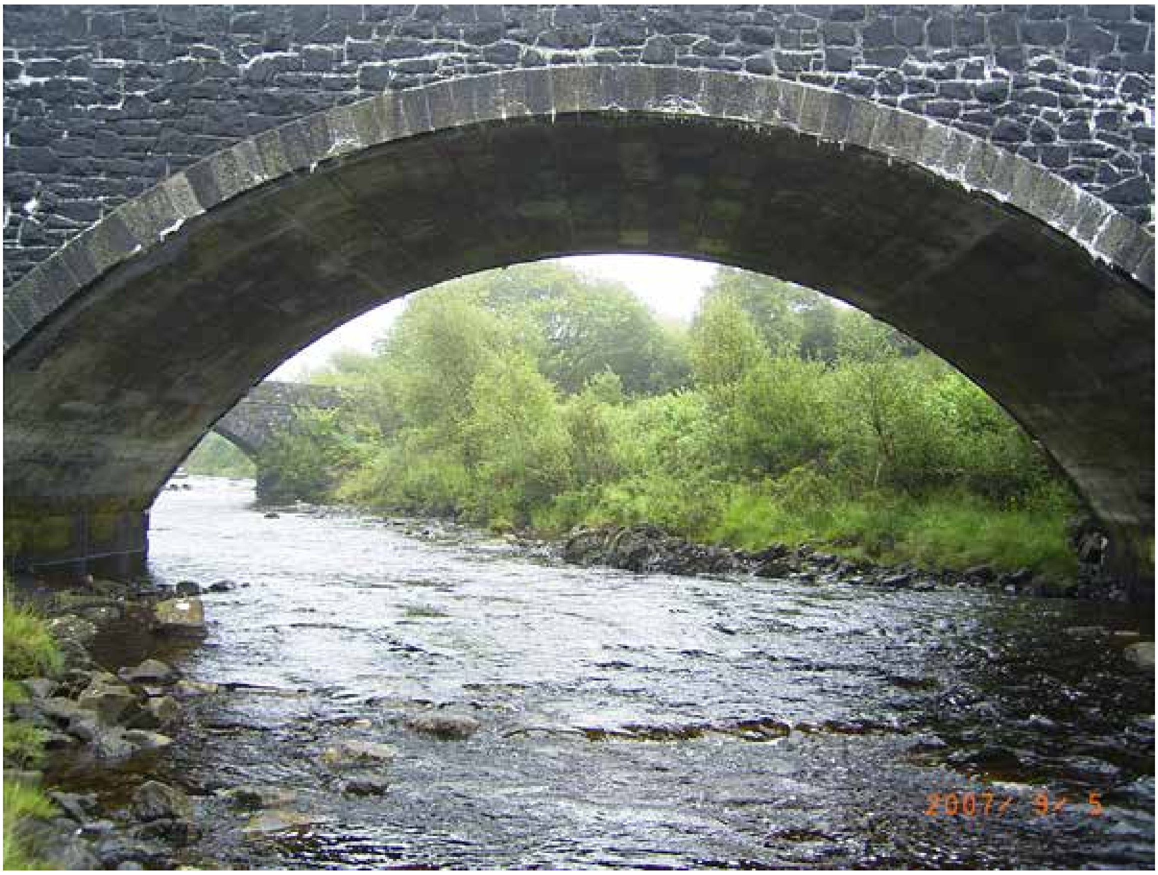


Figure 17. Rossal Farm and surrounding fields

Figure 18. Coladoir River

Figure 19. View of houses, moorings and sheep near head of loch

Figure 20. Septic tank

Figure 21. River Abhainn Bail a Mhuillinn

Figure 22. Livestock on shore

Figure 23. Mussel lines near north shore

Figure 24. River Abhainn Buel-ath an Tairbh

Figure 25. Fallow mussel site

Appendix 2

Sampling Plan

PRODUC-TION AREA	SITE NAME	SIN	SPECIES	TYPE OF FISH-ERY	NGR OF RMP	EAST	NORTH	TOLER-ANCE (M)	DEPTH (M)	METHOD OF SAMPLING	FREQ OF SAMPLING	LOCAL AUTHORITY	AUTHORISED SAMPLER(S)	LOCAL AUTHORITY LIAISON OFFICER
Loch Scridain West	Knackan	AB 315 053 08	Mussel	Rope	NM 40790 24000	140790	724000	10	1m	Hand	Monthly	Argyll & Bute Council	Christine McLachlan William MacQuarrie Ewan McDougall Donald Campbell	Christine McLachlan
Loch Scridain East	Loch Scridain	AB 314 054 08	Mussel	Rope	NM 45970 24790	145970	724790	10	1m	Hand	Monthly	Argyll & Bute Council	Christine McLachlan William MacQuarrie Ewan McDougall Donald Campbell	Christine McLachlan

Appendix 3

Tables of Typical Faecal Bacteria Concentrations

Summary of faecal coliform concentrations (cfu 100ml-1) for different treatment levels and

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 x 10^{7*} (+)	1.4 x 10^{7}	2.0 x 10^{7}	282	2.8 x 10^{6*} (-)	2.3 x 10^{6}	3.2 x 10^{6}
Crude sewage discharges	252	1.7 x 10^{7*} (+)	1.4 x 10^{7}	2.0 x 10^{7}	79	3.5 x 10^{6*} (-)	2.6 x 10^{6}	4.7 x 10^{6}
Storm sewage overflows					203	2.5 x 10^{6}	2.0 x 10^{6}	2.9 x 10^{6}
Primary	127	1.0 x 10^{7*} (+)	8.4 x 10^{6}	1.3 x 10^{7}	14	4.6 x 10^{6} (-)	2.1 x 10^{6}	1.0 x 10^{7}
Primary settled sewage	60	1.8 x 10^{7}	1.4 x 10^{7}	2.1 x 10^{7}	8	5.7 x 10^{6}		
Stored settled sewage	25	5.6 x 10^{6}	3.2 x 10^{6}	9.7 x 10^{6}	1	8.0 x 10^{5}		
Settled septic tank	42	7.2 x 10^{6}	4.4 x 10^{6}	1.1 x 10^{7}	5	4.8 x 10^{6}		
Secondary	864	3.3 x 10^{5*} (-)	2.9 x 10^{5}	3.7 x 10^{5}	184	5.0 x 10^{5*} (+)	3.7 x 10^{5}	6.8 x 10^{5}
Trickling filter	477	4.3 x 10^{5}	3.6 x 10^{5}	5.0 x 10^{5}	76	5.5 x 10^{5}	3.8 x 10^{5}	8.0 x 10^{5}
Activated sludge	261	2.8 x 10^{5*} (-)	2.2 x 10^{5}	3.5 x 10^{5}	93	5.1 x 10^{5*} (+)	3.1 x 10^{5}	8.5 x 10^{5}
Oxidation ditch	35	2.0 x 10^{5}	1.1 x 10^{5}	3.7 x 10^{5}	5	5.6 x 10^{5}		
Trickling/sand filter	11	2.1 x 10^{5}	9.0 x 10^{4}	6.0 x 10^{5}	8	1.3 x 10^{5}		
Rotating biological contactor	80	1.6 x 10^{5}	1.1 x 10^{5}	2.3 x 10^{5}	2	6.7 x 10^{5}		
Tertiary	179	1.3 x 10^{3}	7.5 x 10^{2}	2.2 x 10^{3}	8	9.1 x 10^{2}		
Reedbed/grass plot	71	1.3 x 10^{4}	5.4 x 10^{3}	3.4 x 10^{4}	2	1.5 x 10^{4}		
Ultraviolet disinfection	108	2.8 x 10^{2}	1.7 x 10^{2}	4.4 x 10^{2}	6	3.6 x 10^{2}		

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.

Source: Kay, D. et al. 2008. Faecal indicator organism concentrations and catchment export coefficients in the UK. Water Research (under editorial consideration).

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}

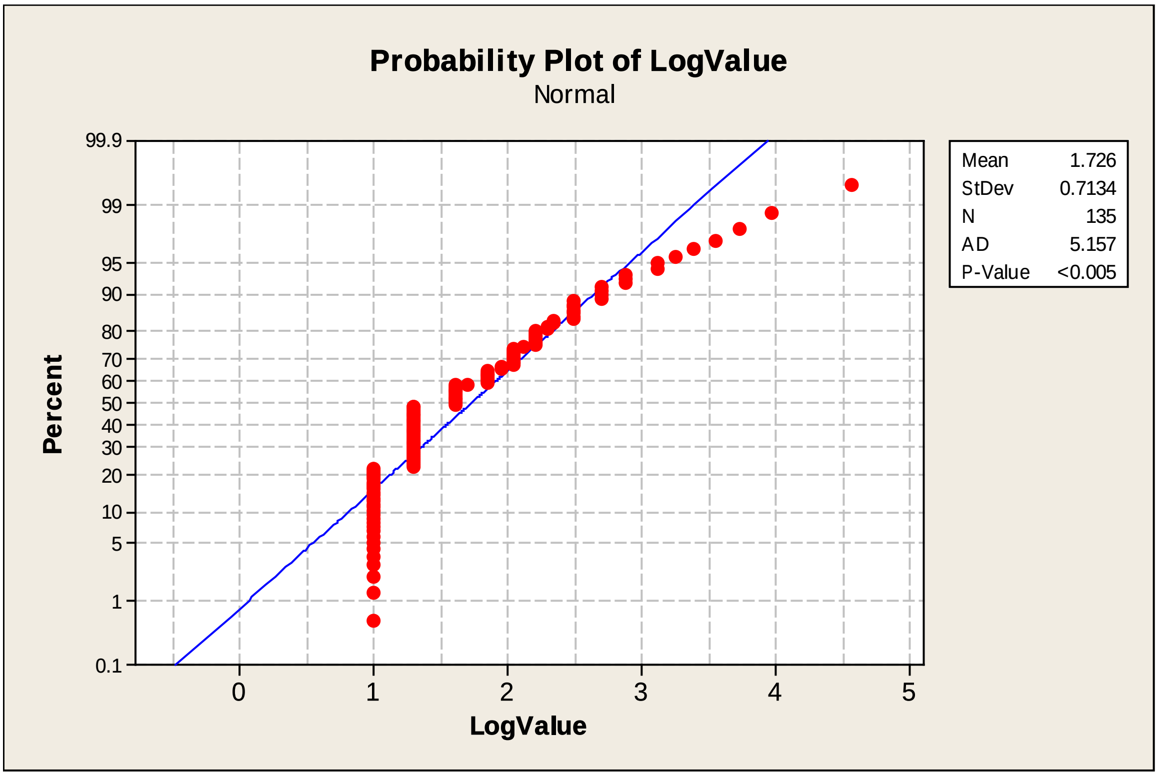
Source: Adapted from Geldreich 1978 by Ashbolt et al in World Health Organisation (WHO) Guidelines, Standards and Health. 2001. Ed. by Fewtrell and Bartram. IWA Publishing, London.

Appendix 4

Statistical data

All analyses were undertaken using log transformed results as this gives a more normal distribution.

Distribution on log scale (with Kolmogorov-Smirnov normality test results)



Section 11.2 T-test comparison of all results by site

Two-sample T for LogValue

ProductionArea	N	Mean	StDev	SE Mean
Loch Scridain East	69	1.753	0.838	0.10
Loch Scridain West	66	1.698	0.559	0.069

Difference = mu (Loch Scridain East) - mu (Loch Scridain West)
Estimate for difference: 0.055
95% CI for difference: (-0.187, 0.297)
T-Test of difference = 0 (vs not =): T-Value = 0.45 P-Value = 0.655 DF = 119

Section 11.2 T-test (paired) comparison of results for samples gathered on the same day by site

Paired T for LogValue (East) - LogValue (West)

	N	Mean	StDev	SE Mean
LogValue (East)	51	1.711	0.834	0.117
LogValue (West)	51	1.650	0.547	0.077
Difference	51	0.062	0.758	0.106

```
95% CI for mean difference: (-0.151, 0.275)
T-Test of mean difference = 0 (vs not = 0): T-Value = 0.58  P-Value = 0.563
```

ANOVA comparison of results by season with (both areas combined) Tukeys comparison

```
Source   DF      SS      MS     F      P
Season    3   8.956  2.985  6.60  0.000
Error   131  59.238  0.452
Total   134  68.194

S = 0.6725   R-Sq = 13.13%   R-Sq(adj) = 11.14%


                         Individual 95% CIs For Mean Based on
                         Pooled StDev
Level   N    Mean   StDev  ------+---------+---------+---------+---
1      31  1.6166  0.7814            (-------*-------)
2      36  1.8353  0.5688                  (------*-------)
3      42  1.9900  0.8235                      (------*------)
4      26  1.2776  0.2680  (--------*-------)
                         ------+---------+---------+---------+---
                             1.20      1.50      1.80      2.10

Pooled StDev = 0.6725


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

Individual confidence level = 98.97%


Season = 1 subtracted from:

Season    Lower   Center   Upper  ---------+---------+---------+---------+
2       -0.2101   0.2187  0.6474              (-------*------)
3       -0.0409   0.3734  0.7878                (------*------)
4       -0.8043  -0.3390  0.1263       (------*-------)
                                  ---------+---------+---------+---------+
                                       -0.60      0.00      0.60      1.20


Season = 2 subtracted from:

Season    Lower   Center    Upper  ---------+---------+---------+---------+
3       -0.2427   0.1548   0.5522             (------*-----)
4       -1.0080  -0.5577  -0.1073    (-------*------)
                                   ---------+---------+---------+---------+
                                        -0.60      0.00      0.60      1.20


Season = 3 subtracted from:

Season    Lower   Center    Upper  ---------+---------+---------+---------+
4       -1.1491  -0.7124  -0.2758  (------*------)
                                   ---------+---------+---------+---------+
                                        -0.60      0.00      0.60      1.20
```

ANOVA comparison of results by season with (Loch Scridain East) Tukeys comparison

```
Source  DF      SS     MS     F      P
Season   3   5.562  1.854  2.86  0.044
Error   65  42.203  0.649
Total   68  47.765

S = 0.8058   R-Sq = 11.64%   R-Sq(adj) = 7.57%


                       Individual 95% CIs For Mean Based on Pooled StDev
Level   N    Mean   StDev   +---------+---------+---------+---------
1      14  1.6803  1.0836            (----------*----------)
2      19  1.8811  0.6088                  (--------*--------)
3      22  2.0136  0.9622                     (-------*--------)
4      14  1.2402  0.2524   (----------*----------)
                            +---------+---------+---------+---------
                          0.80      1.20      1.60      2.00

Pooled StDev = 0.8058


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

Individual confidence level = 98.96%


Season = 1 subtracted from:

Season    Lower   Center   Upper  ---------+---------+---------+---------+
2       -0.5478   0.2008  0.9493            (---------*--------)
3       -0.3933   0.3333  1.0599             (--------*--------)
4       -1.2434  -0.4401  0.3631     (---------*----------)
                                  ---------+---------+---------+---------+
                                       -0.80      0.00      0.80      1.60


Season = 2 subtracted from:

Season    Lower   Center   Upper  ---------+---------+---------+---------+
3       -0.5330   0.1326  0.7982            (--------*-------)
4       -1.3895  -0.6409  0.1077    (--------*--------)
                                  ---------+---------+---------+---------+
                                       -0.80      0.00      0.80      1.60


Season = 3 subtracted from:

Season    Lower   Center    Upper  ---------+---------+---------+---------+
4       -1.5000  -0.7735  -0.0469  (--------*--------)
                                   ---------+---------+---------+---------+
                                        -0.80      0.00      0.80      1.60
```

<u>ANOVA comparison of results by season with (Loch Scridain West) Tukeys comparison</u>

```
Source  DF      SS     MS     F      P
Season   3   3.549  1.183  4.37  0.007
Error   62  16.779  0.271
Total   65  20.328

S = 0.5202   R-Sq = 17.46%   R-Sq(adj) = 13.47%


                       Individual 95% CIs For Mean Based on
                       Pooled StDev
Level   N    Mean   StDev  ------+---------+---------+---------+---
1      17  1.5641  0.4293          (-------*--------)
```

```
2      17  1.7841  0.5344                   (-------*--------)
3      20  1.9641  0.6623                          (------*-------)
4      12  1.3213  0.2901  (---------*---------)
                           ------+---------+---------+---------+---
                               1.20      1.50      1.80      2.10
```

Pooled StDev = 0.5202

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

Individual confidence level = 98.95%

Season = 1 subtracted from:

```
Season    Lower   Center   Upper  ---------+---------+---------+---------+
2       -0.2507   0.2199  0.6906                (-------*-------)
3       -0.0527   0.3999  0.8526                   (-------*------)
4       -0.7602  -0.2428  0.2745        (--------*--------)
                                  ---------+---------+---------+---------+
                                       -0.60      0.00      0.60      1.20
```

Season = 2 subtracted from:

```
Season    Lower   Center   Upper  ---------+---------+---------+---------+
3       -0.2726   0.1800  0.6326               (-------*-------)
4       -0.9801  -0.4628  0.0545     (-------*--------)
                                  ---------+---------+---------+---------+
                                       -0.60      0.00      0.60      1.20
```

Season = 3 subtracted from:

```
Season    Lower   Center    Upper  ---------+---------+---------+---------+
4       -1.1438  -0.6428  -0.1418  (-------*--------)
                                   ---------+---------+---------+---------+
                                        -0.60      0.00      0.60      1.20
```

Regression analysis (log Result versus rain in previous 2 days, both areas combined).

The regression equation is
logresult for rain = 1.66 + 0.00340 2dayrain

Predictor	Coef	SE Coef	T	P
Constant	1.6592	0.1005	16.51	0.000
2dayrain	0.003400	0.004722	0.72	0.474

S = 0.704226   R-Sq = 0.7%   R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.2571	0.2571	0.52	0.474
Residual Error	71	35.2114	0.4959		
Total	72	35.4684			

Unusual Observations

logresult

Obs	2dayrain	for rain	Fit	SE Fit	Residual	St Resid
22	86.5	1.3010	1.9533	0.3605	-0.6523	-1.08 X
23	86.5	1.0000	1.9533	0.3605	-0.9533	-1.58 X
28	6.0	3.3802	1.6796	0.0874	1.7006	2.43R
32	38.1	4.5563	1.7887	0.1476	2.7676	4.02R
72	0.0	3.7324	1.6592	0.1005	2.0732	2.97R
73	64.9	3.1139	1.8798	0.2623	1.2341	1.89 X

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

Regression analysis (log Result versus rain in previous 2 days, Loch Scridain East).

The regression equation is
logres rain = 1.68 + 0.00763 2dayrain

Predictor	Coef	SE Coef	T	P
Constant	1.6799	0.1799	9.34	0.000
2dayrain	0.007627	0.007916	0.96	0.342

S = 0.884600   R-Sq = 2.7%   R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.7266	0.7266	0.93	0.342
Residual Error	34	26.6056	0.7825		
Total	35	27.3322			

Unusual Observations

Obs	2dayrain	logres rain	Fit	SE Fit	Residual	St Resid
11	86.5	1.000	2.340	0.600	-1.340	-2.06RX
15	38.1	4.556	1.971	0.247	2.586	3.04R
35	0.0	3.732	1.680	0.180	2.052	2.37R
36	64.9	3.114	2.175	0.436	0.939	1.22 X

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

Regression analysis (log Result versus rain in previous 2 days, Loch Scridain West).

The regression equation is
logres rain = 1.65 - 0.00252 2dayrain

Predictor	Coef	SE Coef	T	P
Constant	1.65255	0.09376	17.63	0.000
2dayrain	-0.002518	0.004742	-0.53	0.599

S = 0.467039   R-Sq = 0.8%   R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0615	0.0615	0.28	0.599
Residual Error	35	7.6344	0.2181		
Total	36	7.6959			

```
Unusual Observations

             logres
Obs  2dayrain    rain     Fit  SE Fit  Residual  St Resid
 12      86.5  1.3010  1.4347  0.3646   -0.1337     -0.46 X
 35      10.9  2.6990  1.6251  0.0768    1.0739      2.33R
 37       0.0  2.6990  1.6525  0.0938    1.0464      2.29R

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

<u>ANOVA comparison of log Result versus rainfall quartile (previous 2 days, both areas combined).</u>

```
Source  DF      SS     MS     F      P
rq2d     3   0.946  0.315  0.63  0.598
Error   69  34.522  0.500
Total   72  35.468

S = 0.7073   R-Sq = 2.67%   R-Sq(adj) = 0.00%


                        Individual 95% CIs For Mean Based on
                        Pooled StDev
Level   N    Mean   StDev  ----+---------+---------+---------+-----
Q1     20  1.7788  0.7285             (-----------*------------)
Q2     17  1.4960  0.4992  (-------------*-------------)
Q3     17  1.7356  0.6320          (------------*-------------)
Q4     19  1.7699  0.8838            (------------*------------)
                           ----+---------+---------+---------+-----
                             1.25      1.50      1.75      2.00

Pooled StDev = 0.7073
```

<u>ANOVA comparison of log Result versus rainfall quartile (previous 2 days, Loch Scridain East).</u>

```
Source  DF      SS     MS     F      P
rq2d     3   1.268  0.423  0.52  0.672
Error   32  26.064  0.814
Total   35  27.332

S = 0.9025   R-Sq = 4.64%   R-Sq(adj) = 0.00%


                        Individual 95% CIs For Mean Based on
                        Pooled StDev
Level   N    Mean   StDev  ---+---------+---------+---------+------
Q1     10  1.8425  0.8676         (-----------*----------)
Q2      8  1.4774  0.6599  (------------*------------)
Q3      8  1.7287  0.7850      (------------*------------)
Q4     10  1.9982  1.1512           (-----------*-----------)
                           ---+---------+---------+---------+------
                            1.00      1.50      2.00      2.50

Pooled StDev = 0.9025
```

<u>ANOVA comparison of log Result versus rainfall quartile (previous 2 days, Loch Scridain West).</u>

```
Source  DF     SS     MS     F      P
rq2d     3  0.424  0.141  0.64  0.594
```

Error	33	7.272	0.220
Total	36	7.696	

S = 0.4694   R-Sq = 5.51%   R-Sq(adj) = 0.00%

```
                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev  --+---------+---------+---------+-------
Q1     10  1.7152  0.5988          (-----------*-----------)
Q2      9  1.5125  0.3417  (-----------*------------)
Q3      9  1.7418  0.5093          (------------*-----------)
Q4      9  1.5163  0.3597  (------------*-----------)
                          --+---------+---------+---------+-------
                          1.25      1.50      1.75      2.00
```

Pooled StDev = 0.4694

Regression analysis (log Result versus rain in previous 7 days, both areas combined).

The regression equation is
logresult for rain = 1.58 + 0.00297 7dayrain

Predictor	Coef	SE Coef	T	P
Constant	1.5823	0.1300	12.17	0.000
7dayrain	0.002975	0.002539	1.17	0.245

S = 0.700057   R-Sq = 1.9%   R-Sq(adj) = 0.5%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.6727	0.6727	1.37	0.245
Residual Error	71	34.7957	0.4901		
Total	72	35.4684			

Unusual Observations

Obs	7dayrain	logresult for rain	Fit	SE Fit	Residual	St Resid
28	84	3.3802	1.8316	0.1386	1.5486	2.26R
32	38	4.5563	1.6959	0.0820	2.8604	4.11R
39	114	1.3010	1.9208	0.2050	-0.6198	-0.93 X
72	37	3.7324	1.6924	0.0822	2.0400	2.93R

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

Regression analysis (log Result versus rain in previous 7 days, Loch Scridain East).

The regression equation is
logres rain = 1.58 + 0.00477 7dayrain

Predictor	Coef	SE Coef	T	P
Constant	1.5849	0.2325	6.82	0.000
7dayrain	0.004769	0.004420	1.08	0.288

S = 0.881632   R-Sq = 3.3%   R-Sq(adj) = 0.5%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.9048	0.9048	1.16	0.288
Residual Error	34	26.4273	0.7773		
Total	35	27.3322			

Unusual Observations

Obs	7dayrain	logres rain	Fit	SE Fit	Residual	St Resid
15	38	4.556	1.767	0.147	2.789	3.21R
35	37	3.732	1.761	0.148	1.971	2.27R

R denotes an observation with a large standardized residual.

Regression analysis (log Result versus rain in previous 7 days, Loch Scridain West).

The regression equation is
logres rain = 1.59 + 0.00085 7dayrain

Predictor	Coef	SE Coef	T	P
Constant	1.5909	0.1226	12.97	0.000
7dayrain	0.000853	0.002461	0.35	0.731

S = 0.468113   R-Sq = 0.3%   R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0263	0.0263	0.12	0.731
Residual Error	35	7.6695	0.2191		
Total	36	7.6959			

Unusual Observations

Obs	7dayrain	logres rain	Fit	SE Fit	Residual	St Resid
12	110	1.3010	1.6846	0.1909	-0.3835	-0.90 X
35	25	2.6990	1.6121	0.0842	1.0869	2.36R
37	42	2.6990	1.6269	0.0774	1.0721	2.32R

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

ANOVA comparison of log Result versus rainfall quartile (previous 7 days, both sites combined) with Tukeys comparison.

Source	DF	SS	MS	F	P
rq7d	3	4.515	1.505	3.35	0.024
Error	69	30.953	0.449		
Total	72	35.468			

S = 0.6698   R-Sq = 12.73%   R-Sq(adj) = 8.94%

```
                        Individual 95% CIs For Mean Based on
                        Pooled StDev
Level   N   Mean   StDev  --+---------+---------+---------+-------
```

```
Q1     19  1.2963  0.2682  (--------*--------)
Q2     14  1.9454  0.5279                 (----------*---------)
Q3     18  1.8669  1.0249                (--------*--------)
Q4     22  1.7579  0.6241              (-------*-------)
                           --+---------+---------+---------+-------
                           1.05      1.40      1.75      2.10

Pooled StDev = 0.6698


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of rq7d

Individual confidence level = 98.95%


rq7d = Q1 subtracted from:

rq7d    Lower  Center   Upper  ---+---------+---------+---------+------
Q2     0.0286  0.6491  1.2697             (----------*---------)
Q3    -0.0088  0.5706  1.1501             (---------*--------)
Q4    -0.0902  0.4616  1.0134           (---------*--------)
                               ---+---------+---------+---------+------
                               -0.60      0.00      0.60      1.20


rq7d = Q2 subtracted from:

rq7d    Lower   Center   Upper  ---+---------+---------+---------+------
Q3    -0.7063  -0.0785  0.5493   (----------*---------)
Q4    -0.7899  -0.1875  0.4148  (---------*---------)
                                ---+---------+---------+---------+------
                                -0.60      0.00      0.60      1.20


rq7d = Q3 subtracted from:

rq7d    Lower   Center   Upper  ---+---------+---------+---------+------
Q4    -0.6690  -0.1090  0.4509    (--------*---------)
                                ---+---------+---------+---------+------
                                -0.60      0.00      0.60      1.20
```

<u>ANOVA comparison of log Result versus rainfall quartile (previous 7 days, Loch Scridain East).</u>

```
Source  DF      SS     MS     F      P
rq7d     3   3.740  1.247  1.69  0.189
Error   32  23.592  0.737
Total   35  27.332

S = 0.8586   R-Sq = 13.68%   R-Sq(adj) = 5.59%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev  ---------+---------+---------+---------+
Q1      9  1.2341  0.1327  (---------*--------)
Q2      7  1.8992  0.5795           (----------*----------)
Q3      9  2.0743  1.3593              (---------*--------)
Q4     11  1.9077  0.8157             (--------*--------)
                           ---------+---------+---------+---------+
                                 1.20      1.80      2.40      3.00

Pooled StDev = 0.8586
```

ANOVA comparison of log Result versus rainfall quartile (previous 7 days, Loch Scridain West) with Tukeys comparison.

Source	DF	SS	MS	F	P
rq7d	3	1.699	0.566	3.12	0.039
Error	33	5.997	0.182		
Total	36	7.696			

S = 0.4263   R-Sq = 22.07%   R-Sq(adj) = 14.99%

```
                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  ---------+---------+---------+---------+
Q1     10  1.3522  0.3476  (-------*------)
Q2      7  1.9916  0.5129                (--------*--------)
Q3      9  1.6595  0.5362         (-------*--------)
Q4     11  1.6080  0.3211         (-------*------)
                           ---------+---------+---------+---------+
                                 1.40      1.75      2.10      2.45
```

Pooled StDev = 0.4263

Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of rq7d

Individual confidence level = 98.94%

rq7d = Q1 subtracted from:

```
rq7d    Lower  Center   Upper  ------+---------+---------+---------+---
Q2     0.0704  0.6394  1.2083                (---------*--------)
Q3    -0.2232  0.3073  0.8378            (--------*--------)
Q4    -0.2486  0.2558  0.7603            (-------*--------)
                               ------+---------+---------+---------+---
                                 -0.60      0.00      0.60      1.20
```

rq7d = Q2 subtracted from:

```
rq7d    Lower   Center   Upper  ------+---------+---------+---------+---
Q3    -0.9139  -0.3320  0.2498   (--------*---------)
Q4    -0.9418  -0.3835  0.1747  (---------*--------)
                                ------+---------+---------+---------+---
                                  -0.60      0.00      0.60      1.20
```

rq7d = Q3 subtracted from:

```
rq7d    Lower   Center   Upper  ------+---------+---------+---------+---
Q4    -0.5704  -0.0515  0.4674       (--------*--------)
                                ------+---------+---------+---------+---
                                  -0.60      0.00      0.60      1.20
```

Regression analysis (log Result versus water temperature)

The regression equation is
logresult for temp = 0.421 + 0.121 Temp

Predictor	Coef	SE Coef	T	P
Constant	0.4209	0.4891	0.86	0.398
Temp	0.12098	0.03892	3.11	0.005

S = 0.689501   R-Sq = 28.7%   R-Sq(adj) = 25.7%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	4.5934	4.5934	9.66	0.005
Residual Error	24	11.4099	0.4754		
Total	25	16.0033			

Unusual Observations

Obs	Temp	logresult for temp	Fit	SE Fit	Residual	St Resid
21	14.0	3.732	2.115	0.155	1.618	2.41R

R denotes an observation with a large standardized residual.

Circular-linear correlation of wind direction and log result

CIRCULAR-LINEAR CORRELATION
Loch Scridain
Analysis begun: 06 February 2008 12:33:26

Variables (& observations)	r	p
Angles & Linear (69)	0.275	0.007

Appendix 5

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

<u>Background processes</u>

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

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

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

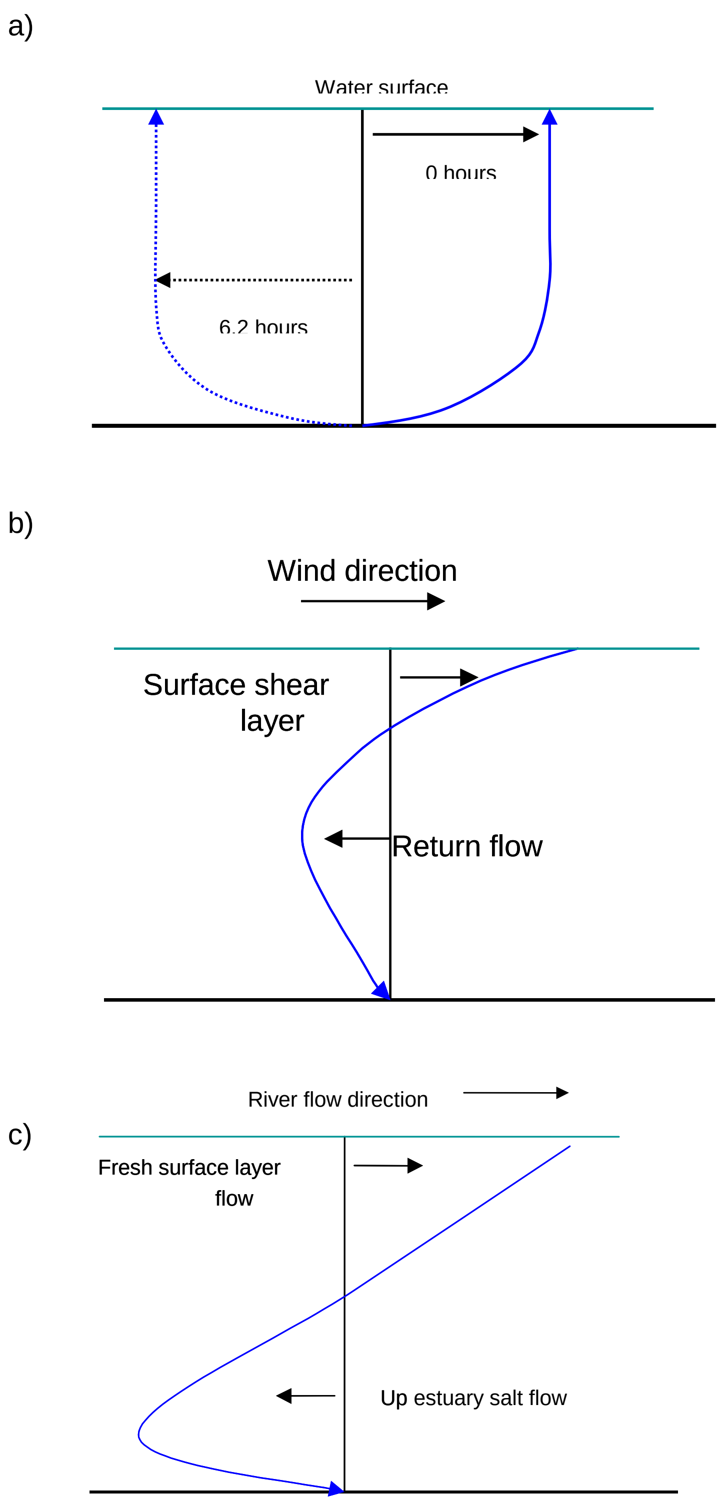


Figure 1. Typical vertical profiles for currents generated by different mechanisms. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main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

In sea lochs, currents associated with *windrows* can transport contaminated water near the shore to production areas further offshore. Windrows are often generated by winds directed along the main length of the loch. Figure 2 illustrates the water movements associated with this. As can be seen the water circulates in a series of cells that draw material across the loch at right angles to the wind direction. This is a particularly common situation for lochs with high land on either side as these tend to act as a steering mechanism to align winds along the water body.

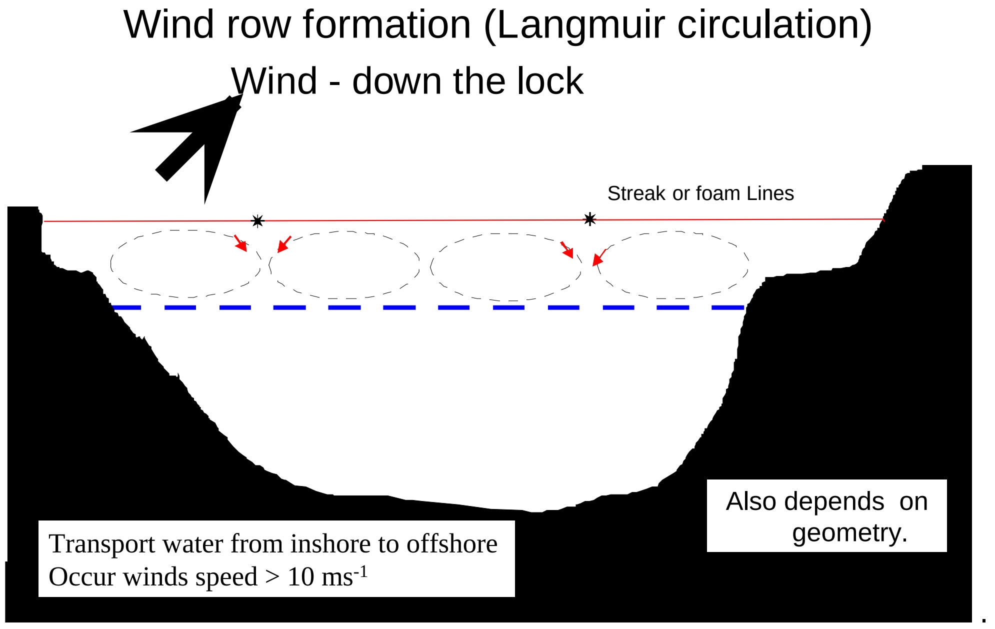


Figure 2: Schematic of wind driven 'wind row' currents. View is down the loch.The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.