Scottish Sanitary Survey Project

Sanitary Survey Report
Islay: Loch Gruinart Craigens
AB 094
December 2007

Cefas

FOOD STANDARDS AGENCY SCOTLAND
Buidheann Inbhe-Bìdhe an Alba

Report Distribution – Islay: Loch Gruinart Craigens

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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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Acknowledgements

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Christine McLachlan
Mr. Craig Archibald
SEPA Registry Office Dingwall
Scottish Water
Callan Duck, Sea Mammal Research Unit, St Andrews
Dr. Alan Lilly, Macaulay Land Research Institute

1. General Description

Loch Gruinart is a north-facing loch 6.2km in length located on the northwest coast of the island of Islay. Islay lies off the south western coast of Scotland. The loch has a maximum depth of 8 metres and a flushing time of one day.

It is predominated by tidal flats that are important for overwintering wildfowl.

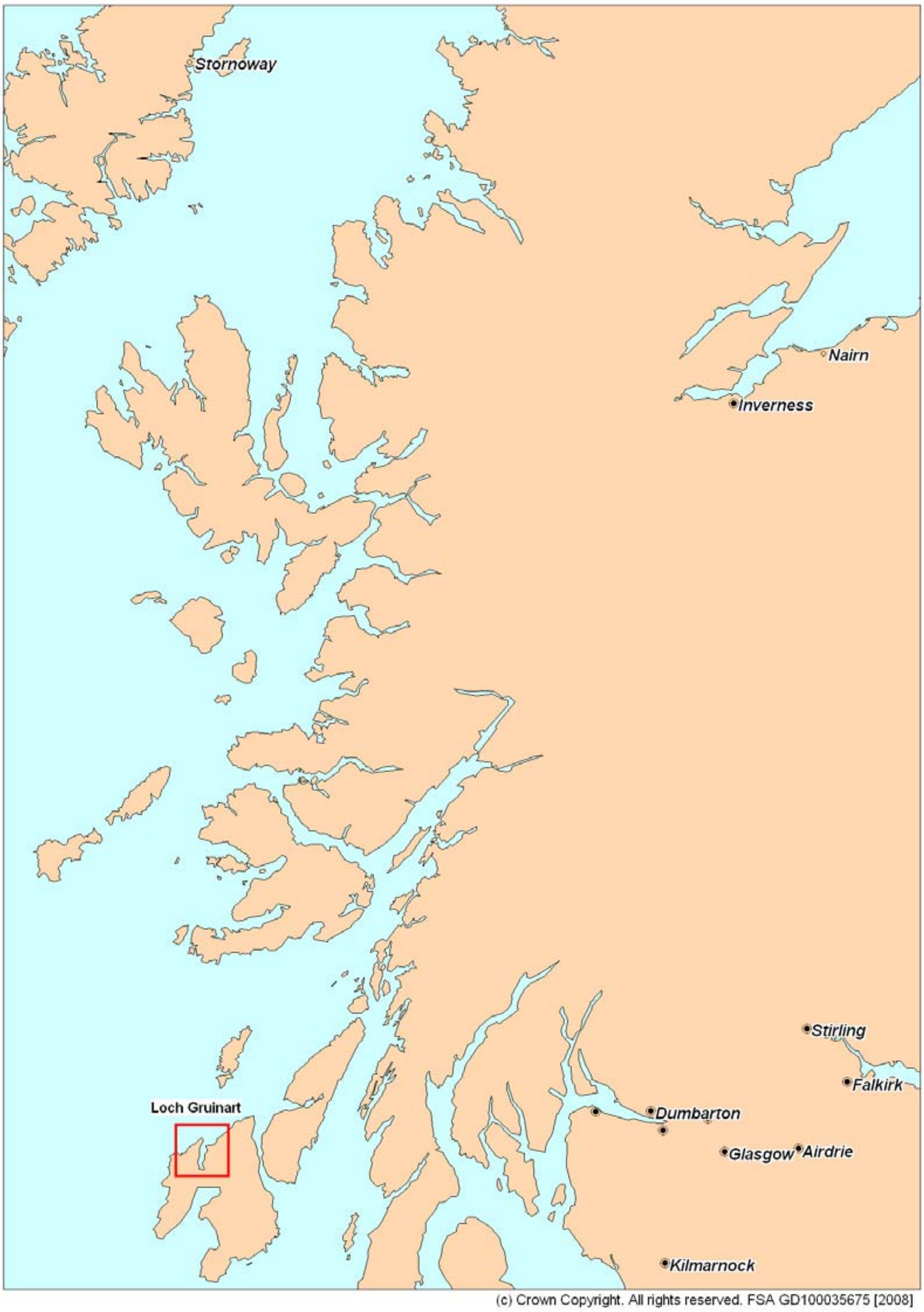


Figure 1.1. Location of Loch Gruinart, Islay

2. Fishery

Table 2.1 Islay fishery

Production Area	Site	SIN	Species
Islay	Loch Gruinart Craigens	AB 094 011 13	Pacific oysters

Local Authority: Argyll & Bute Council
Harvester: Mr. Craig Archibald

Pacific oysters are grown in triangular bags on trestles between the eastern shore of the loch and the central channel. The approximate boundary of the farm is indicated on the map as described by the grower on the day of survey. Trestles are mainly concentrated at the north end of the site, but a few of the trestles are kept at the south end of the site next to the processing shed.

Harvesting on site can occur year round, but an important harvest period is in the summer, when oysters are supplied to passing trade and through local festivals and events. Oysters take 2-3 years to reach marketable size.

The Islay production area corresponds with a designated shellfish growing water.

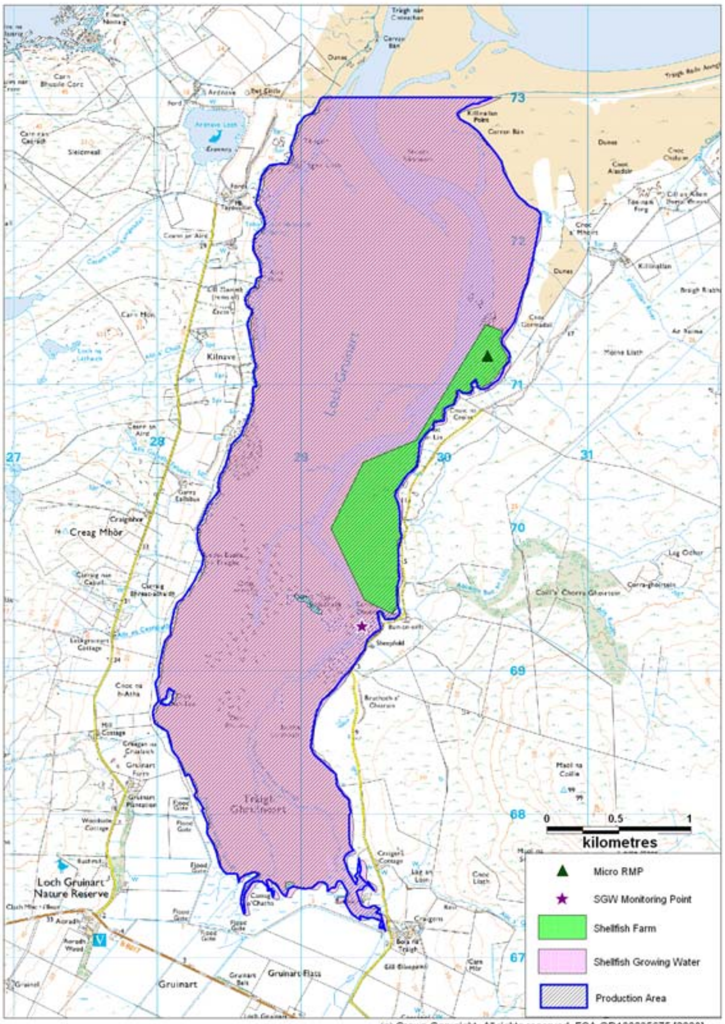
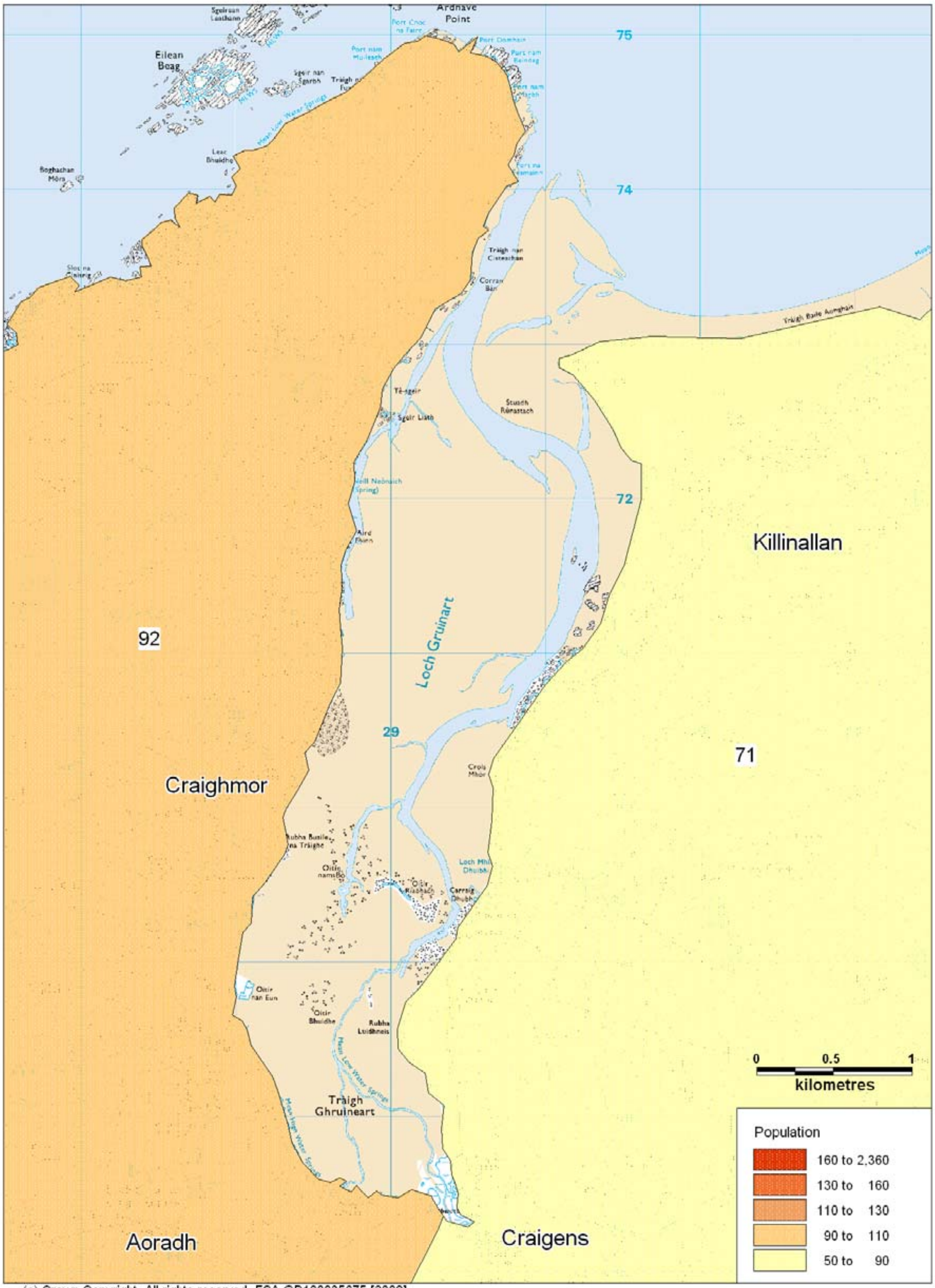


Figure 2.1 Loch Gruinart oyster fishery

3. Human population

Figure 3.1 below shows information obtained from the General Register Office for Scotland on the population within the census output in the vicinity of Loch Gruinart.



Population data Census Data (2001) - General Register Office for Scotland

Figure 3.1 Population of Loch Gruinart in adjacent census output areas

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

60QD000105	71
60QD000104	92

There are very few settlements immediately bordering Loch Gruinart. On the western coast is the small settlement of Craigmhor, on the southern coast are the settlements of Aoradh and Craigens and on the northeast coast is the settlement of Killinallan. Most of the population is concentrated on the southern shore of the loch and any associated faecal pollution from human sources will be concentrated in this area.

4. Sewage Discharges

No community septic tank discharges were identified by Scottish Water in the area of Loch Gruinart.

A number of private septic discharges were registered with SEPA and are detailed in Table 4.1. Discharge volumes are given in population equivalent (PE). No bacteriological data were available for these discharges. A study of faecal coliform concentrations in sewage found a geometric mean concentration of 7.2×10^6 colony forming units (cfu) per 100ml of settle septic tank effluent under base flow conditions (See table, Appendix 3).

Table 4.1 SEPA discharge consents

Consent No.	Name	Type	PE	Grid Ref
CAR/R/1012902	Tigh an Arish	Septic tank to land	5	NR 2797 7009
CAR/R/1013288	Lek Gruinart Cottage	Septic tank to land	5	NR 2769 6924
CAR/R/1014876	Mullin Cottage	Septic tank Abhainn a Mhuillinn	5	NR 2758 6852
CAR/R/1014875	Woodside Cottage	Septic tank to land	5	NR 2774 6796
CAR/R/1014862	1 & 2 Bushmill Cottages	Septic tank to land	10	NR 2776 6762
CAR/R/1014864	Aoradh Bothy & Farmhouse	Septic tank to land	12	NR 2756 6716
CAR/R/1014863	Grainel Farm	Septic tank to land	5	NR 2699 6679

These discharges all lie along the western shore of Loch Gruinart and are identified on the map in Figure 4.2. Of these, Mullin Cottage, Woodside Cottage, Bushmill Cottages, Aoradh Bothy & Farmhouse and Grainel Farm are all registered as being with the RSPB and so are likely to used as accommodation for birdwatchers and as such are subject to seasonal fluctuations in use.

Only one of the above discharges is to water, specifically to the Abhainn a Mhuillinn. The remaining discharges are soakaways. The efficiency of these will be dependent upon the soil types observed in the area and function of the septic tank itself. It is possible that if these were not functioning properly they could adversely affect the oyster fishery, particularly on an outgoing tide. Additionally due to the transient nature of occupation at the RSPB there may be a seasonal affect to discharges as occupancy is likely to be higher during bird migrations in the spring and autumn as well as during the winter when migratory geese are in residence at the loch.

During the course of the shoreline survey, a further two discharges to water were identified. One discharges to a stream on the west side of the loch, and is believed to serve three houses. The other discharges into Abhain Bun an Uillt, a stream which discharges on the east side of the loch at the southern end of the fishery, and serves the oyster processing shed.

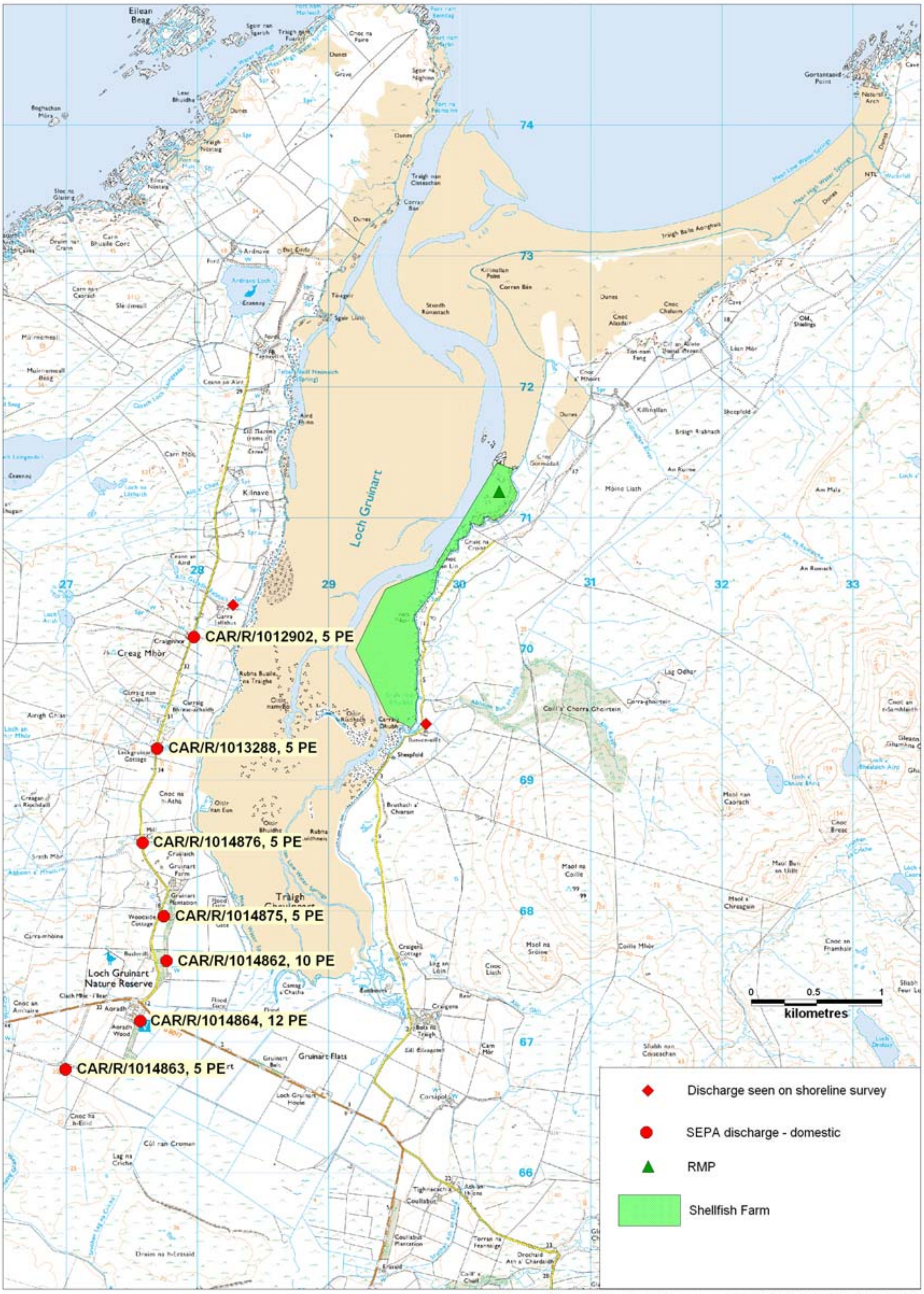


Figure 4.1 Sewage discharges at Loch Gruinart

5. Geology and soils

Component soils and their associations were identified using uncoloured soil maps (scale 1:50,000) obtained from the Macaulay Institute. The relevant soil associations and component soils were then investigated to establish basic characteristics. From the maps seven main soil types were identified: 1) humus-iron podzols, 2) brown forest soils, 3) calcareous regosols, brown calcareous regosols, calcareous gleys, 4) peaty gleys, podzols, rankers, 5) non-calcareous gleys, peaty gleys: some humic gleys, peat, 6) organic soils and 7) alluvial soils (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 (Macaulay Institute, 2007).

Calcareous regosols, brown regosols and calcareous gleys are all characteristically freely draining soils containing free calcium carbonate within their profiles. These soil types have a very low surface % runoff at 14.5% 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. The map of component soils and their associated drainage classes for the area around Loch Gruinart can be found in Figure 5.1.

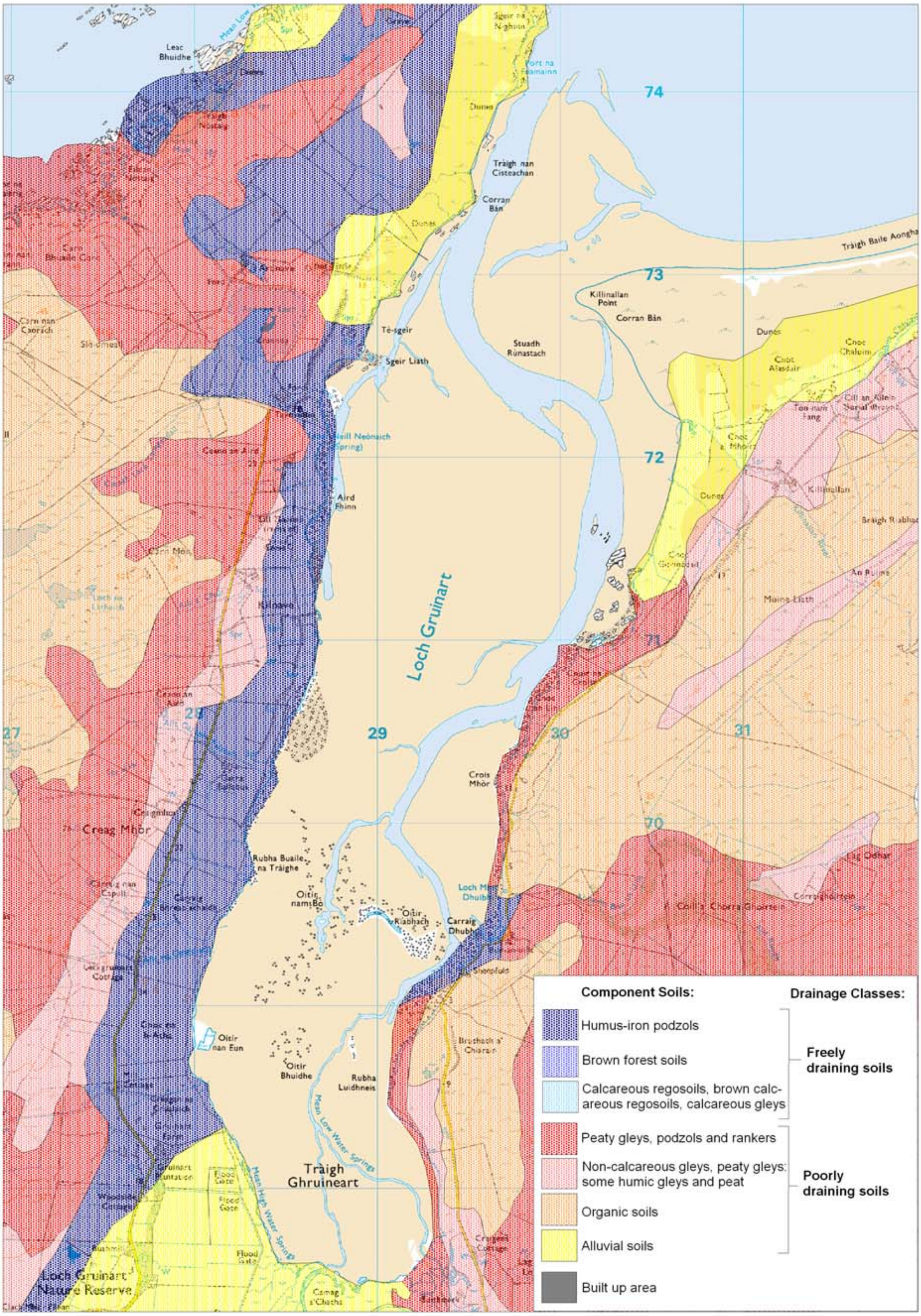


Figure 5.1 Component soils and drainages classes for Loch Gruinart

There are five main types of component soils visible in the area. The first is humus-iron podzols and is concentrated mainly along the western coastline of the loch. The second is non-calcareous gleys, peaty gleys: some humic gleys and peat and is located in several areas. These include a band parallel to the humus-iron podzols and a few areas further inland on the eastern side of the loch.

The third component soil covers peaty gleys, podzols and rankers and is situated in patches inland on the western coast and along the central part of the eastern coastline. The fourth component soil type is organic soils and these are situated on both sides of the loch, further inland, often adjacent to the peaty gleys, podzols and rankers. The final component soil group, alluvial soils are located in several corners of the loch, often close to sand dunes.

The potential for runoff contaminated with *E. coli* from animal waste is higher along the eastern side of the loch, however it is also possible on the western coastline on the very northern and southern tips.

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:

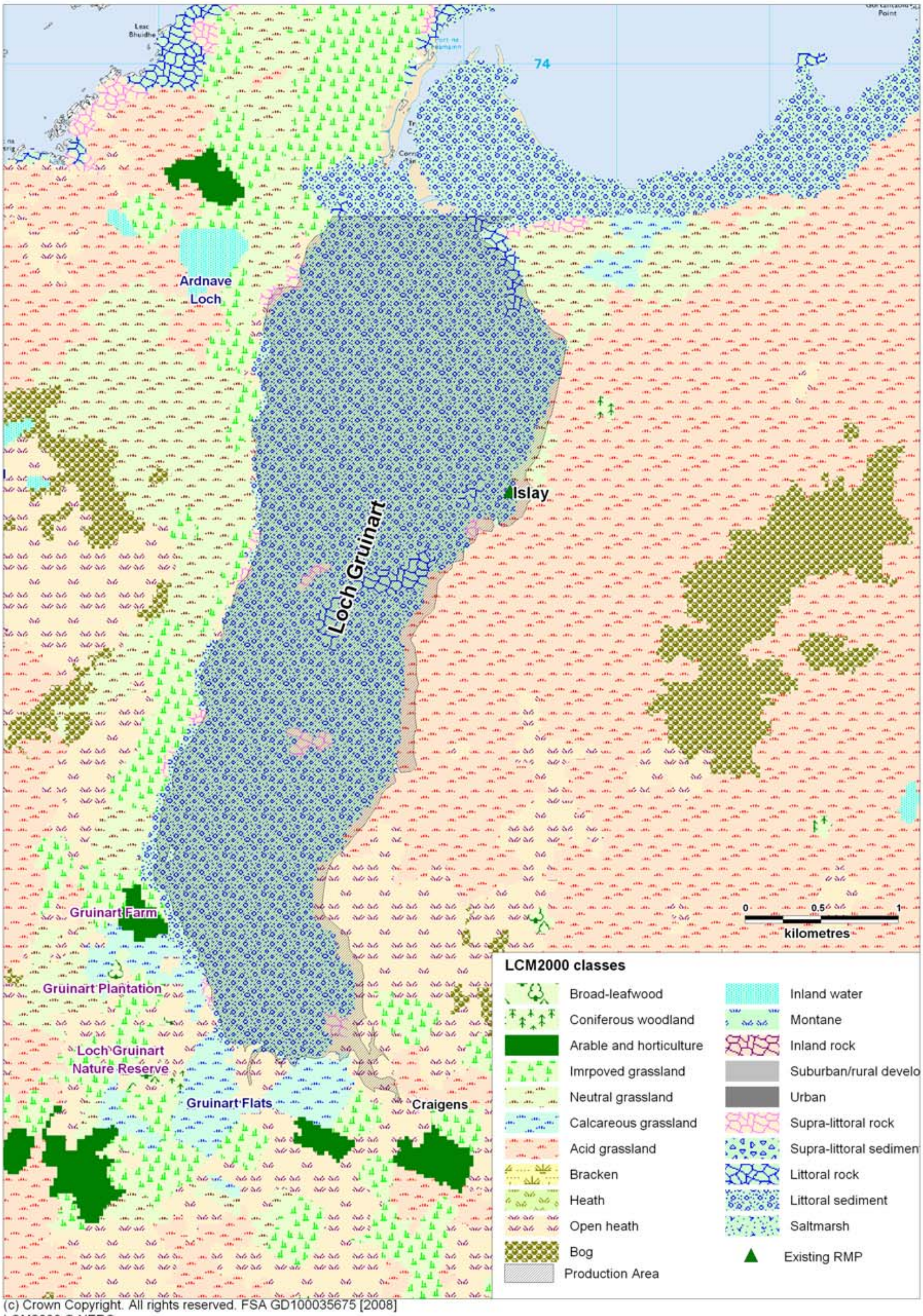


Figure 6.1 LCM2000 class data for Loch Gruinart

The production area of Loch Gruinart is composed of littoral sediment, littoral rock and supra-littoral rock. The land on the eastern side of Loch Gruinart is shown as predominantly acid grassland with some patches of neutral grassland, open heath and improved grassland. The western side of the loch is shown as open heath, neutral grassland and improved grassland with some patches of bog, further inland.

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.

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 only contained a small number of farms making it possible to determine specifics for individual farms.

The only significant sources of information were therefore the shoreline survey and discussion with the harvester who also farms land adjacent to the production area. The shoreline survey only relates to the time of the site visits on 12-13 June and 22 November 2007.

There are three farms adjacent to the production area. On the east and south sides of the loch is Mr. Archibald's farm, which covers an area of around 4500 acres and usually contains approximately 200 cattle, 1100 ewes and 1200 lambs. To the south is a farm owned by the RSPB, which covers around 5000 acres on which are kept approximately 200 cattle and 300 sheep. The farm on the west side of the loch usually contains about 75-100 cattle and 200 sheep.

In most areas of the loch, livestock have free access to the shoreline. Of potential significance is an area of low-lying salt grassland at the head of the loch on the eastern side. At the time of survey, about 400 ewes and lambs were grazing on the area and large amounts of faecal matter were present on the ground. According to Mr. Archibald, this area is especially attractive to the sheep. This area is inundated at larger tides and it is likely that the ebbing tide will carry faecal waste to the oyster trestles. The sheep are removed from this area around the 10th of September and area allowed to return from around 20 October. Mr. Archibald reports that the sheep do not frequent the area as much during the winter months.

In addition, livestock access the streams flowing through the farms to drink, especially during the summer months.

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

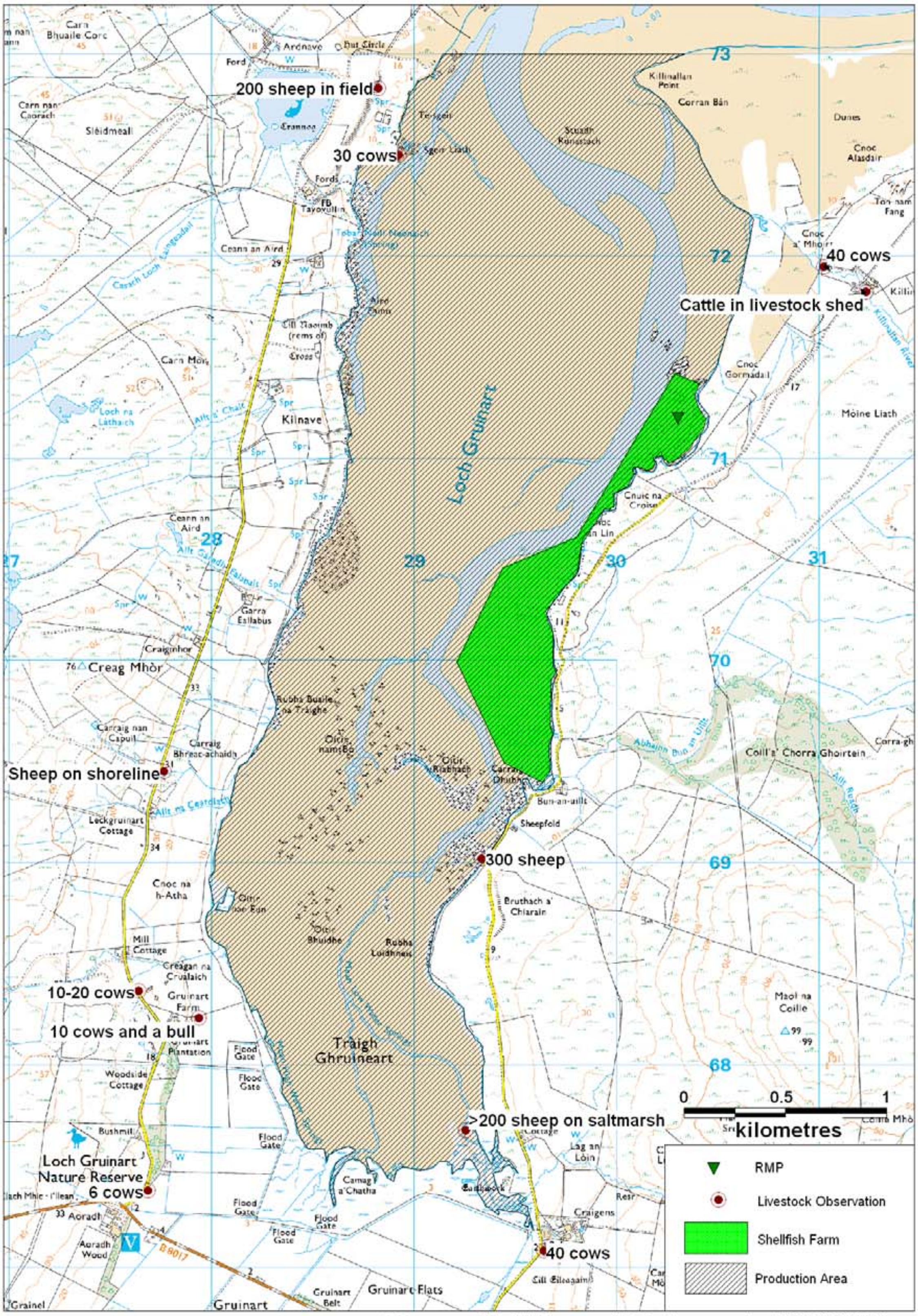


Figure 7.1 Livestock observations at Loch Gruinart, Islay

8. Wildlife

8.1 Pinnipeds

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

The concentrations 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 seal surveys are conducted every 5 years and an estimate of minimum numbers is available through Scottish Natural heritage.

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

Adult grey seals weigh 150-220 kg and adult common seals 50-170 kg. They are estimated to consume between 4 and 8% of their body weight per day in fish, squid, molluscs and crustaceans. No estimates were available of the volume of faeces passed per day per animal, though it is reasonable to assume that what is ingested and not assimilated in the gut must pass as faeces. Assuming 6% of a median body weight for harbour seals of 110 kg, this 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 acquiring resistant bacteria from exposure to human sewage.

Salmonella typhimurium is carried by a number of animal species in addition to the elephant seals described above, 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).

A large colony of grey seals is located outside Loch Gruinart at Nave Island. Pups are surveyed annually and in 2003 (the last year for which data was available) 462 were counted. Adult numbers are estimated to be 3.5 times the pup population (Callan Duck, Sea Mammal Research Unit, St. Andrews, personal communication).

Seals do frequent Loch Gruinart and as many as 50 seals have been observed hauled out on a sand bank approximately 100 metres from the oyster trestles. During the shoreline survey, at least 10 were observed foraging amongst the trestles. Numbers foraging in the loch will depend on prey availability here and elsewhere and is likely to fluctuate.

The seals will be present in the loch year round, though possibly in lower numbers during breeding season (Oct/Nov) and moulting season (Dec-Apr).

8.2 Cetaceans

Due to the shallow depth and tidal nature of Loch Gruinart, cetaceans are not anticipated to frequent the area and so are not considered as a source of contamination.

8.3 Seabirds

While Islay does host some colonies of breeding seabirds, Loch Gruinart does not host significant colonies. Seabirds such as gulls will always be present on the loch but their distribution is likely to be even over time and as such would not materially affect placement of an RMP.

8.4 Other

Loch Gruinart hosts significant populations of waders and overwintering Barnacle geese (*Branta leucopsis*) and White-fronted geese (*Anser albifrons*). The following significant populations were present at the loch during 2006 according to RSPB census numbers:

Table 8.1 Significant bird populations near fishery

Common name	Latin name	Months present	Peak month	Peak numbers
Barnacle goose	*Granta leucopsis*	Sept – April	Oct	25942
White-fronted goose	*Anser albifrons*	Oct-April	Oct	741
Greylag goose	*Anser anser*	Apr-Jun, Aug-Dec	Sep	814
Teal	*Anas crecca*	All year	Jan	1511
Dunlin	*Calidris alpina*	Nov-May, Aug-Sep	Dec	682
Golden plover	*Pluvaialis apricaria*	Oct-Feb, Mar	Nov	631
Wigeon	*Anas penelope*	Sep-May	Feb	386

The geese will settle on the exposed sand but feed on the fields around the loch, so dropping will be spread widely across the area as the birds graze. The mean *E. coli* concentration for Canada geese (*Branta canadensis*) found in a study conducted in the USA was 3.6×10^5 cfu g^{-1} wet weight of faeces (Middleton and Ambrose, 2005). A separate study collected information on the average weights and faecal coliform (FC) concentrations of faecal samples collected from both Canada geese and Ring-billed gulls (*Larus delawarensis*) (Alderisio and DeLuca, 1999). The mean sample weight from 171 geese was 8.35 g per goose with an average FC concentration of 1.53×10^4 cfu/g. The mean sample weight from 249 gulls was 0.48 g per gull with an average FC concentration of 3.68×10^8 cfu/g.

Anecdotally, geese are reputed to pass approximately their body weight in faeces daily. This estimate was confirmed as reasonable using data available from published research (Dean Cliver, Food Safety Unit, University of California Davis, personal communication).

Wading birds are also present in the loch for much of the year, though numbers tend to be lowest in summer and higher during the remainder of the year. Two of the larger shorebird populations at Loch Gruinart are represented in the table above. Both species are present in largest numbers during November and December.

Both waterfowl and shorebirds are present within the loch in large numbers during the winter months. Their droppings may present a significant source of *E. coli* to the oyster fishery during that time.

9. Meteorological data

The nearest weather station is located at Eallabus, approximately 6 km to the south 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 334 days. Wind data was not recorded at this station. It is likely that rainfall experienced at Eallabus 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 80 km to the NNW 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 on Islay, but are liable to differ on any given day. Although both the production area and the weather station are located on low lying islands which are exposed to the west, 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 Islay production area.

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 Eallabus (Islay)

Due to the high 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 *.

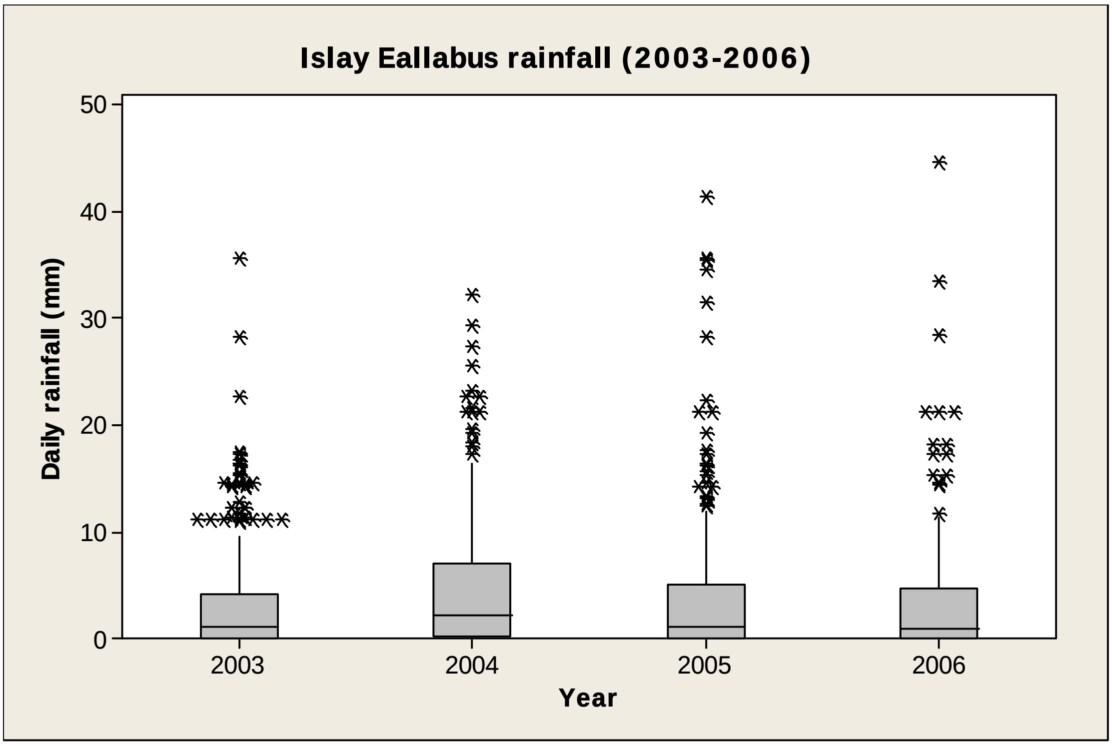


Figure 9.1 Boxplot of daily rainfall at Eallabus by year

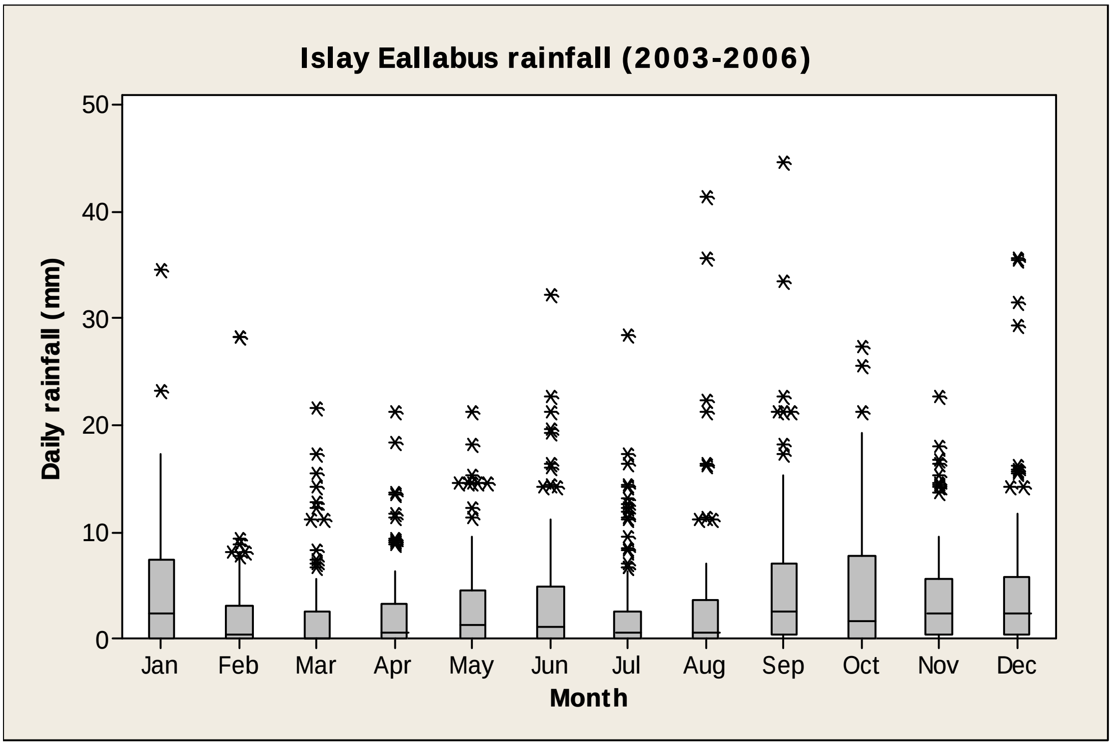


Figure 9.2 Boxplot of daily rainfall at Eallabus by month

Higher rainfall was recorded at Eallabus from September through to January.

It can therefore be expected that levels of rainfall dependant 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 in the autumn.

9.2 Wind

Wind data collected at the Tiree weather station is summarised by season and presented in figures 9.5 to 9.8.

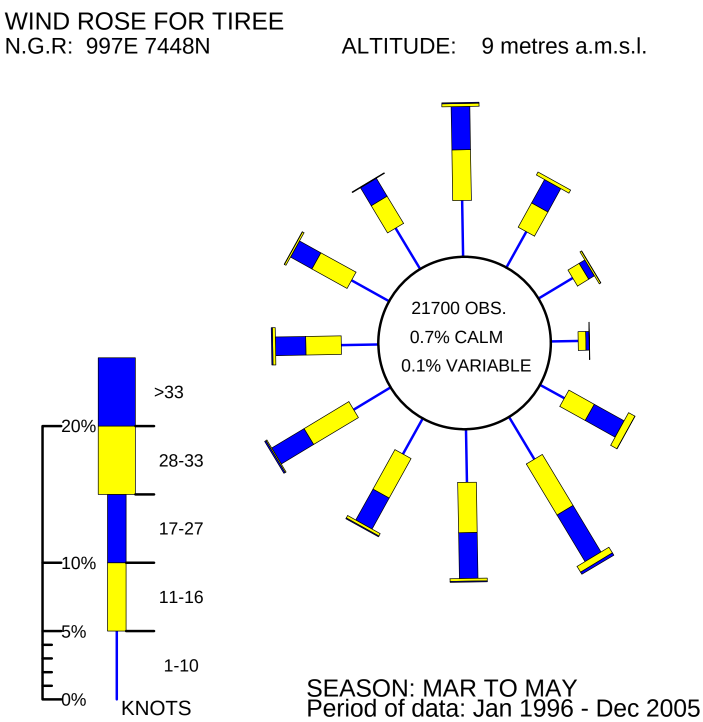


Figure 9.3 Wind rose for Tiree (March to May)

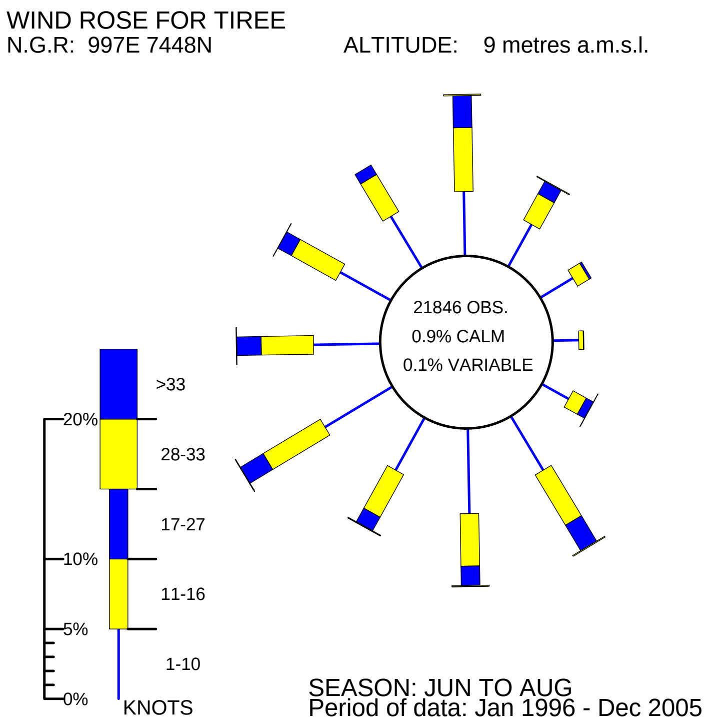


Figure 9.4 Wind rose for Tiree (June to August)

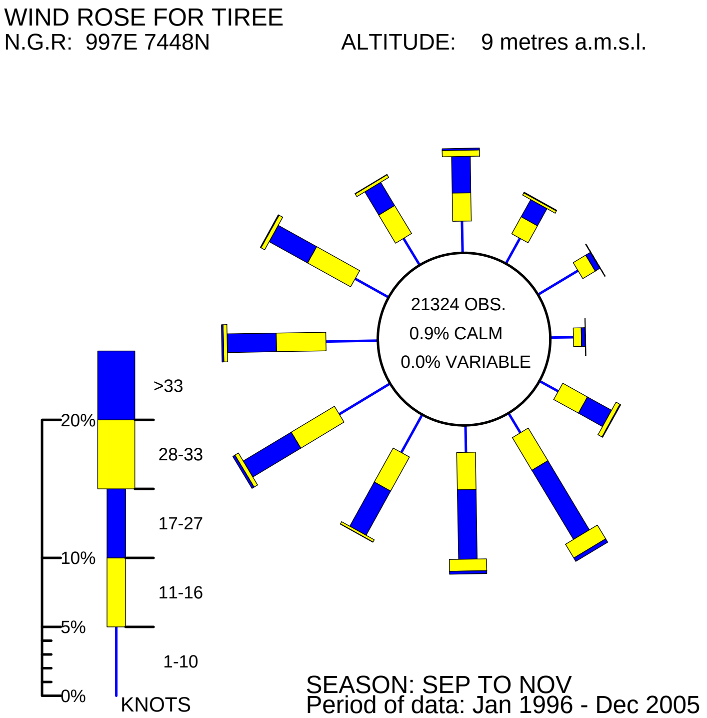


Figure 9.5 Wind rose for Tiree (September to November)

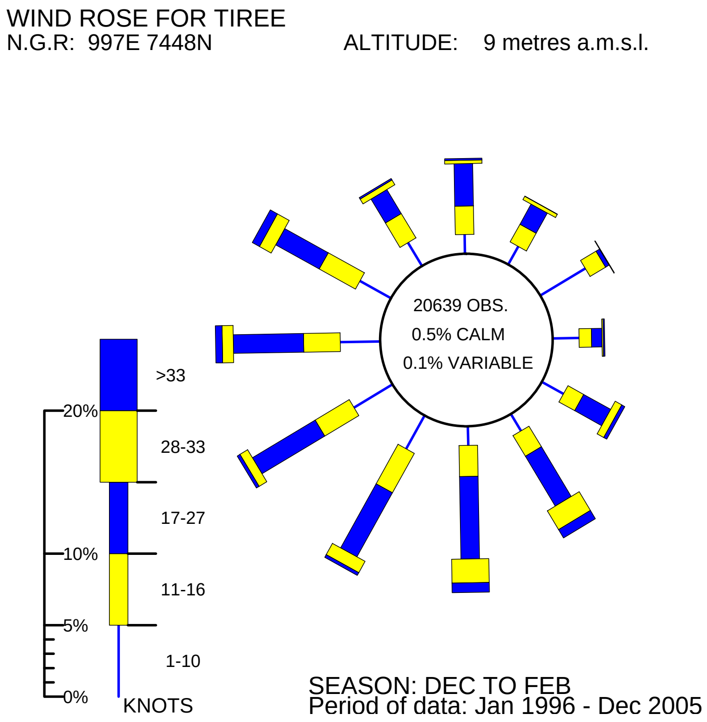


Figure 9.6 Wind rose for Tiree (December to February)

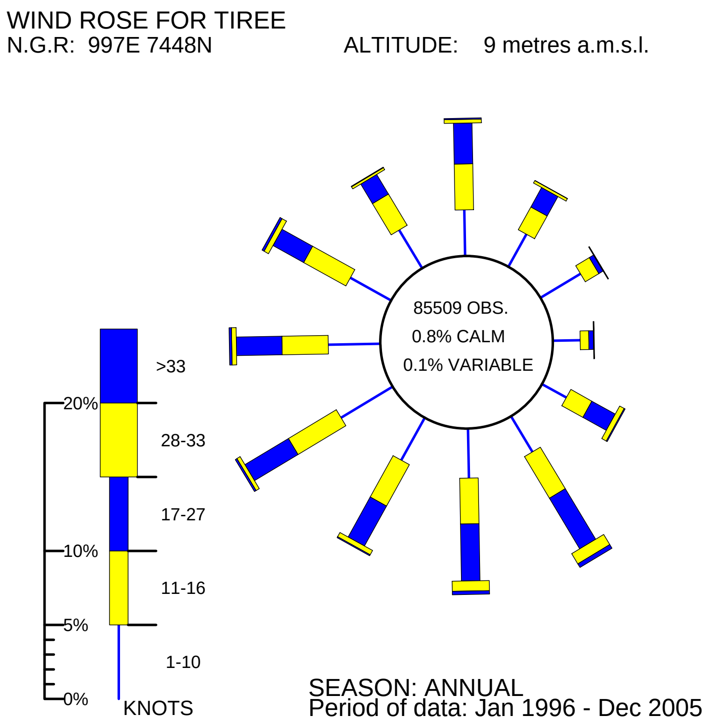


Figure 9.7 Wind rose for Tiree (All year)

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

Loch Gruinart is located in the north west of Islay and is open to the north. Some shelter from winds may be offered by the low lying land to the south. More shelter will be offered from winds by the low hills to the west and higher ground to the east of the Loch. Therefore, circulation of water in the Loch is most likely to be affected by winds from the north, and to a lesser extent the south. 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 loch.

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. In the case of Loch Gruinart, which almost completely fills and empties on each tidal cycle, tidally driven circulation is likely to be much more important.

10. Current and Historical Classification Status

The area was provisionally classified in 2001, and given a full classification in 2002. The classification history is presented in Table 10.1. Currently, the area is classified as a year seasonal A/B. A map of the current production area is presented in Figure 10.1.

Table 10.1 - Classification history

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

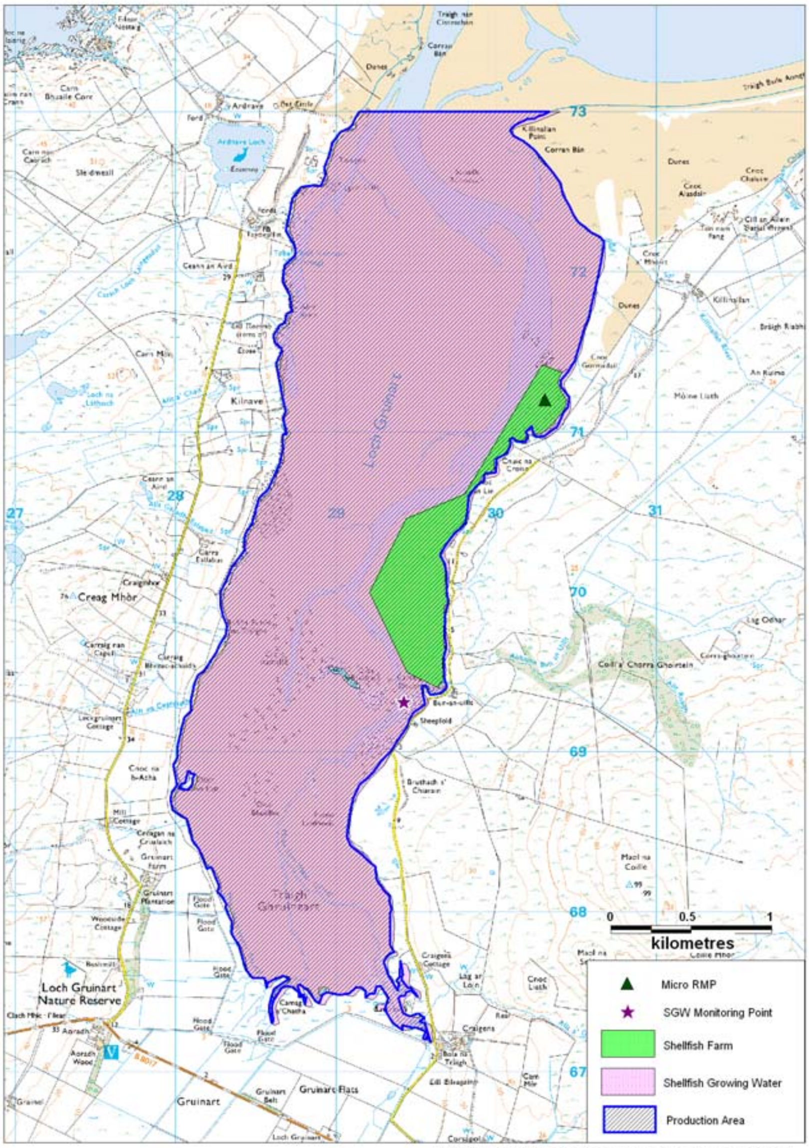


Figure 10.1 – Loch Gruinart production area

11. Historical *E. coli* Data

11.1 Validation of historical data

All oyster samples taken from Islay 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. One sample had a result reported as <20, it was assigned a nominal value of 10, and in the two instances the result was reported as >18000, it was assigned a nominal value of 36000 for statistical assessment and graphical presentation. Three samples with an analysis date of 3 days post collection were rejected. All *E. coli* results are reported in most probable number per 100g of shellfish flesh and intervalvular fluid.

11.2 Summary of microbiological results by sites

All samples were taken from the same location, at the RMP, which falls within the farm and production area boundaries. 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.

Table 11.1 Summary of results from Islay

Sampling summary	
Production area	Islay
Site	Loch Gruinart Craigens
Species	Pacific oyster
SIN	AB 0994 011 13
Location	NR303712
Total no. of samples	63
No. 1999	2
No. 2000	8
No. 2001	5
No. 2002	6
No. 2003	11
No. 2004	8
No. 2005	11
No. 2006	12
Results summary (*E. coli* mpn/100g)	
Minimum	<20
Maximum	>18000
Median	310
Geometric mean	346.2
90 percentile	5020
95 percentile	15310
No. exceeding 230/100g	34 (54%)
No. exceeding 1000/100g	13 (21%)
No. exceeding 4600/100g	7 (11%)
No. exceeding 18000/100g	2 (3%)

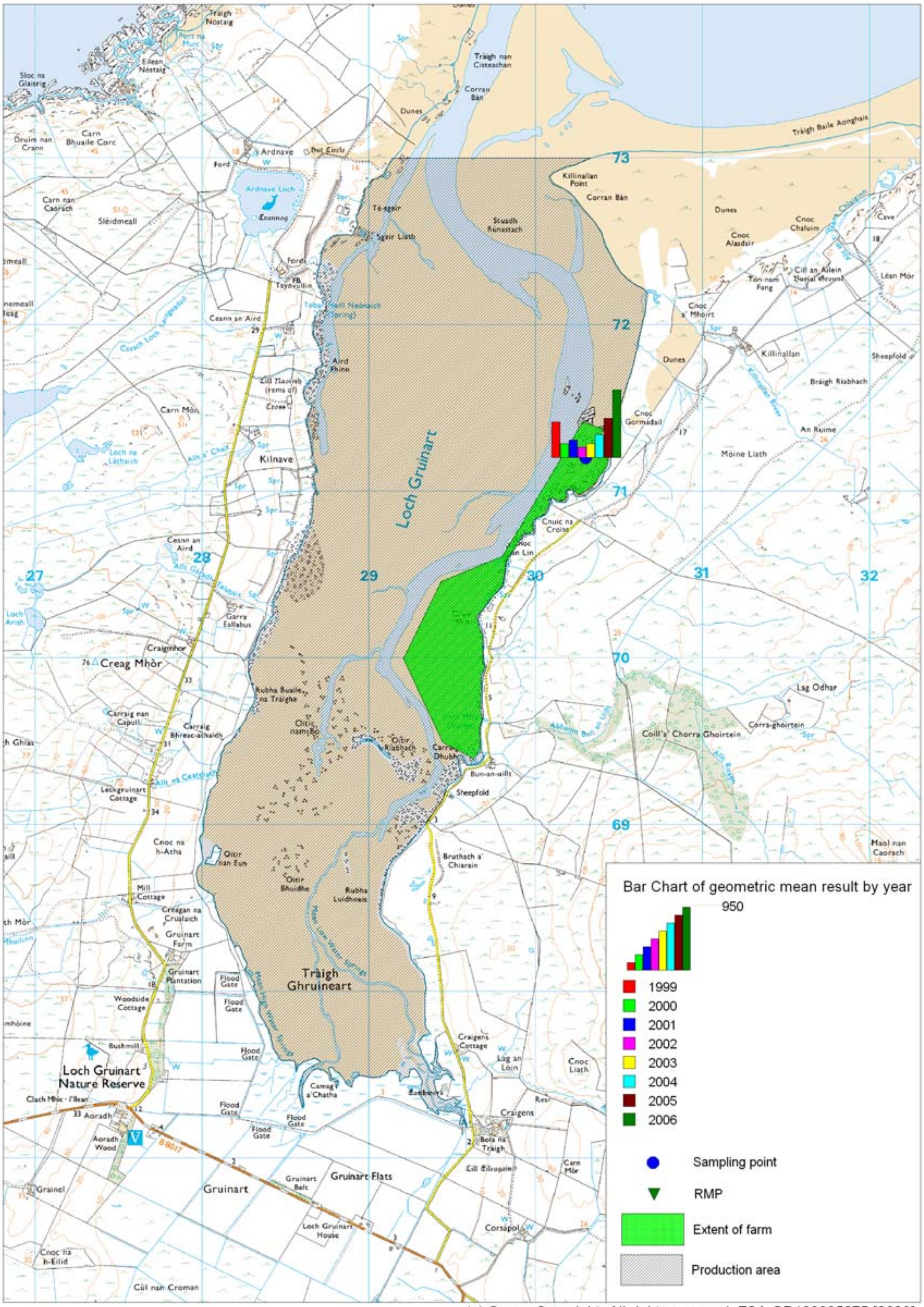


Figure 11.1 - Sampling location and geometric mean result by year

11.3 Temporal pattern of results

Figures 11.2 and 11.3 present scatter plots of individual results against date for all samples taken from Islay. Both are fitted with trend lines to help highlight any apparent underlying trends or cycles. Figure 11.2 is fitted with a line indicating the geometric mean of the previous 5 samples, the current sample and the following 6 samples. Figure 11.3 is fitted with a loess smoother, a regression based smoother line calculated by the Minitab statistical software. Figure 11.4 presents the geometric mean of results by month (+ 2 times the standard error).

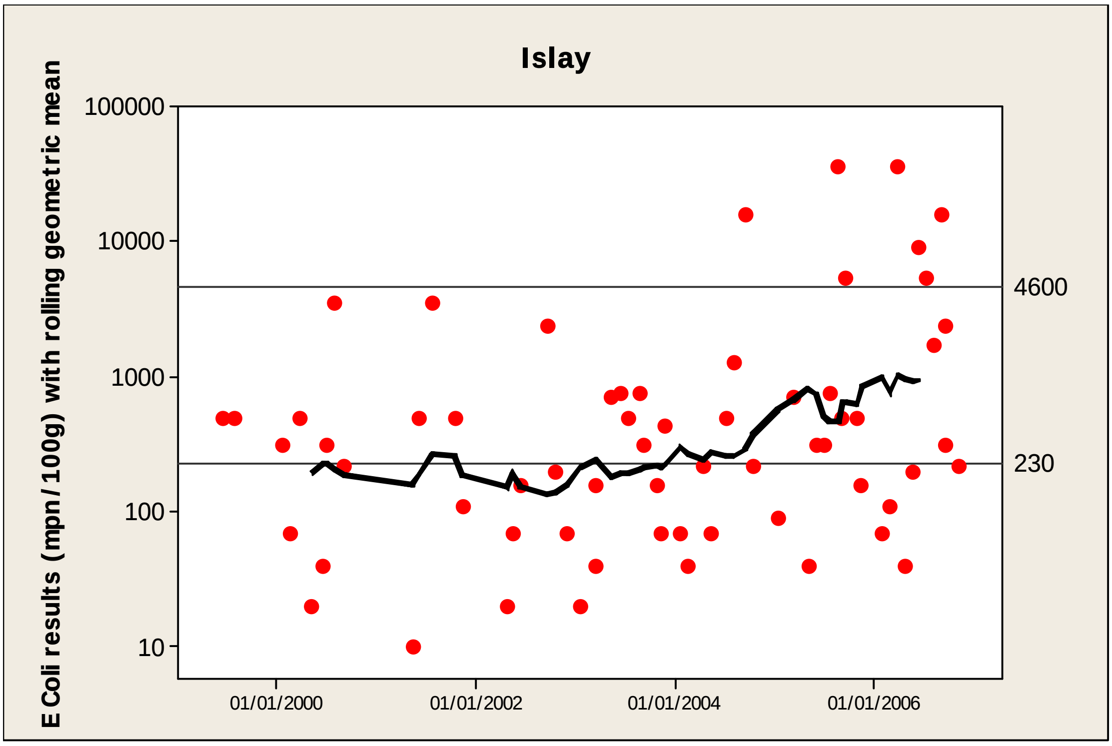


Figure 11.2 - Scatterplot of shellfish *E. coli* result by date with rolling geometric mean

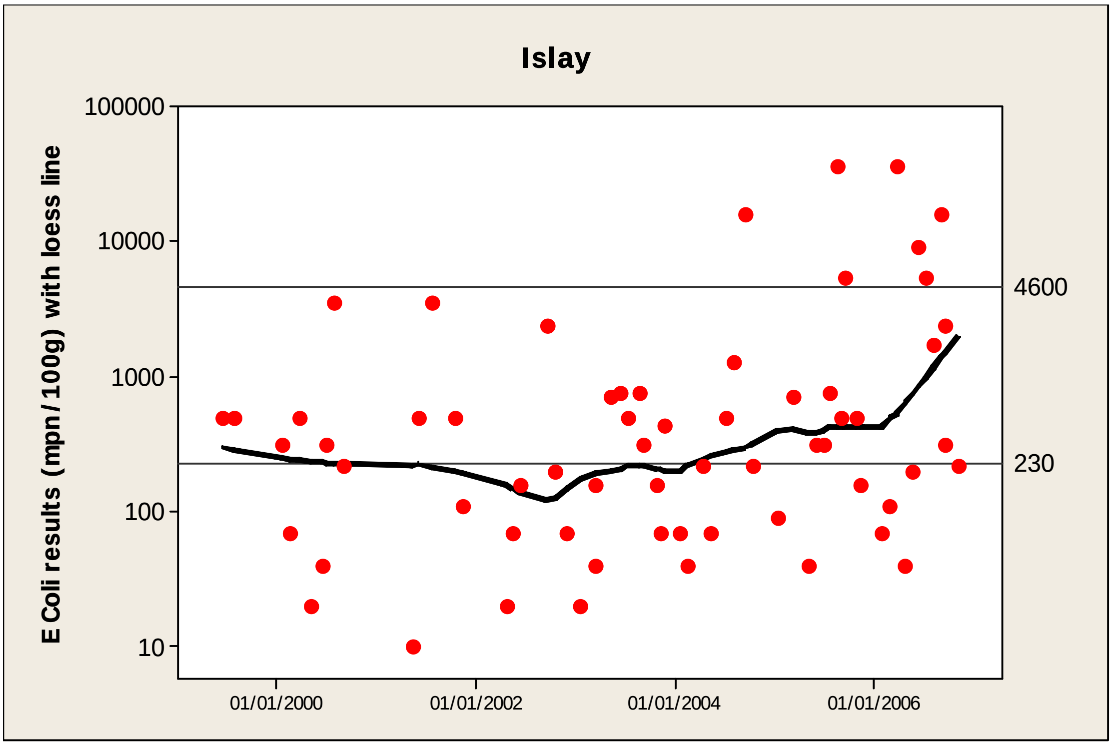


Figure 11.3 - Scatterplot of shellfish *E. coli* result by date with loess smoother

Figures 11.1 to 11.3 suggest a marked deterioration in microbiological quality between 2004 and 2006.

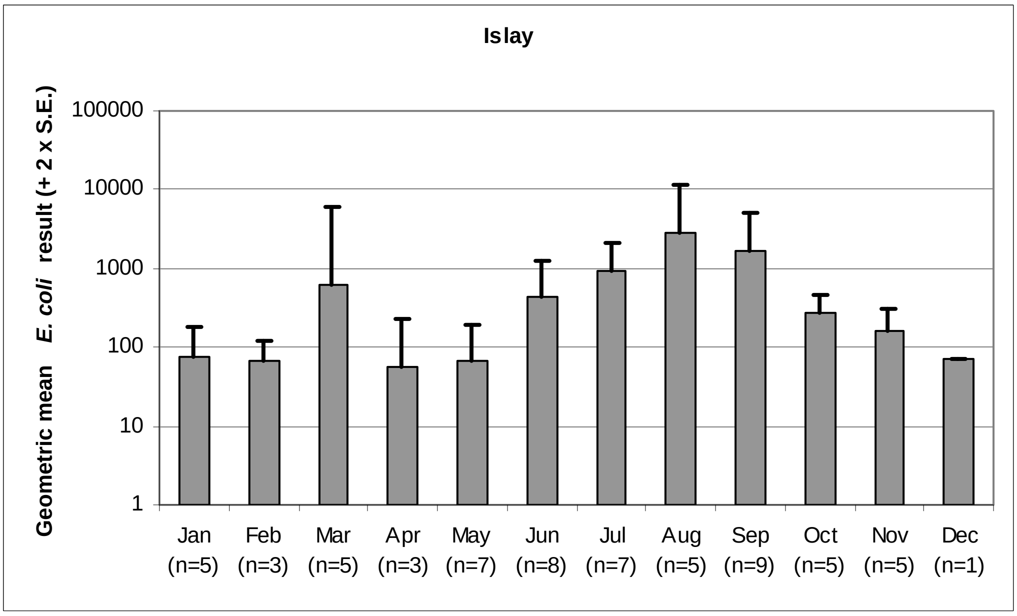


Figure 11.4 - Geometric mean shellfish *E. coli* result by month

Highest mean results were in June to September, and also in March. The peak in March is due to one sample with a result of >18000.

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 63 samples taken from Islay from the start of sampling in 1999 to the end of 2006.

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).

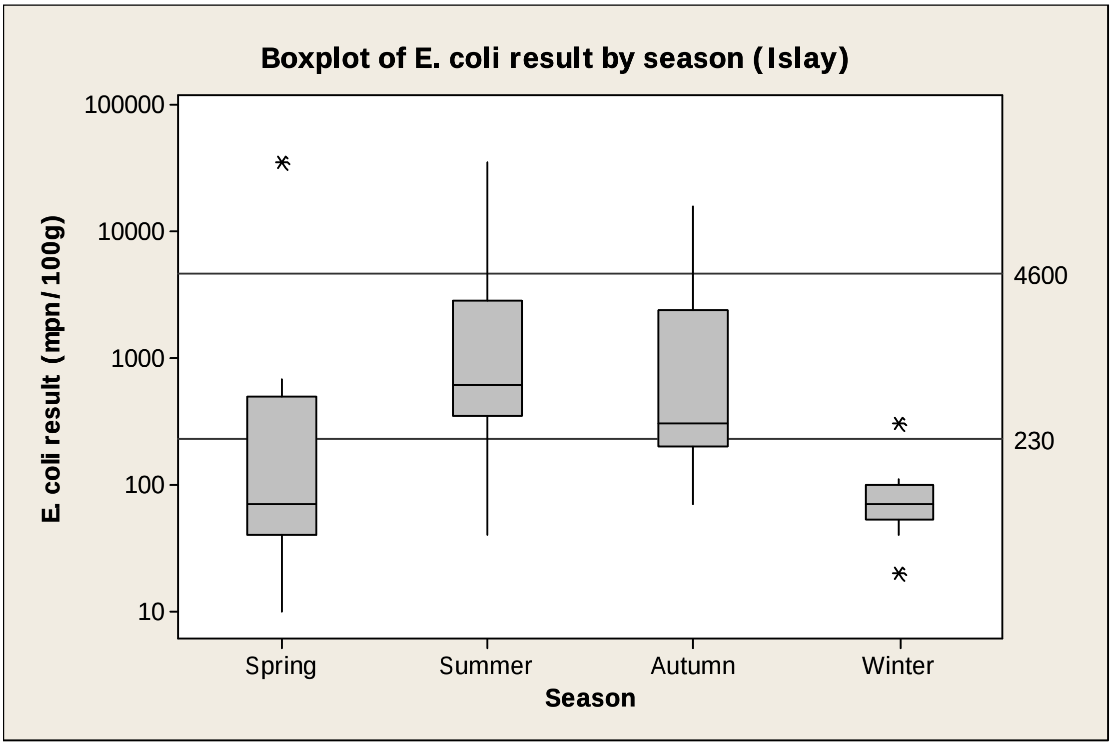


Figure 11.5 Boxplot of shellfish *E. coli* result by season

A significant seasonal effect was observed (One-way ANOVA, p=0.000, Appendix 4), with higher results in the summer and autumn compared to the winter and spring.

11.4.2 Analysis of results by recent rainfall

The nearest weather station is located at Eallabus, approximately 6 km to the south of the production area. Rainfall records were available for 2003-2006 inclusive, although total daily rainfall was not recorded on 334 days of this period.

The coefficient of determination was calculated for *E. coli* results and rainfall in the previous 2 days at Eallabus. Figure 11.6 presents a scatterplot of *E. coli* result and rainfall, with a best fit line derived by regression. Figure 11.8 presents a boxplot of results by rainfall quartile (quartile 1 = 0 to 0.3 mm, quartile 2 = 0.3 to 4.4 mm, quartile 3 = 4.4 to 11.0 mm, quartile 4 = more than 11.0 mm). Rainfall data was only available for 33 of the 63 samples.

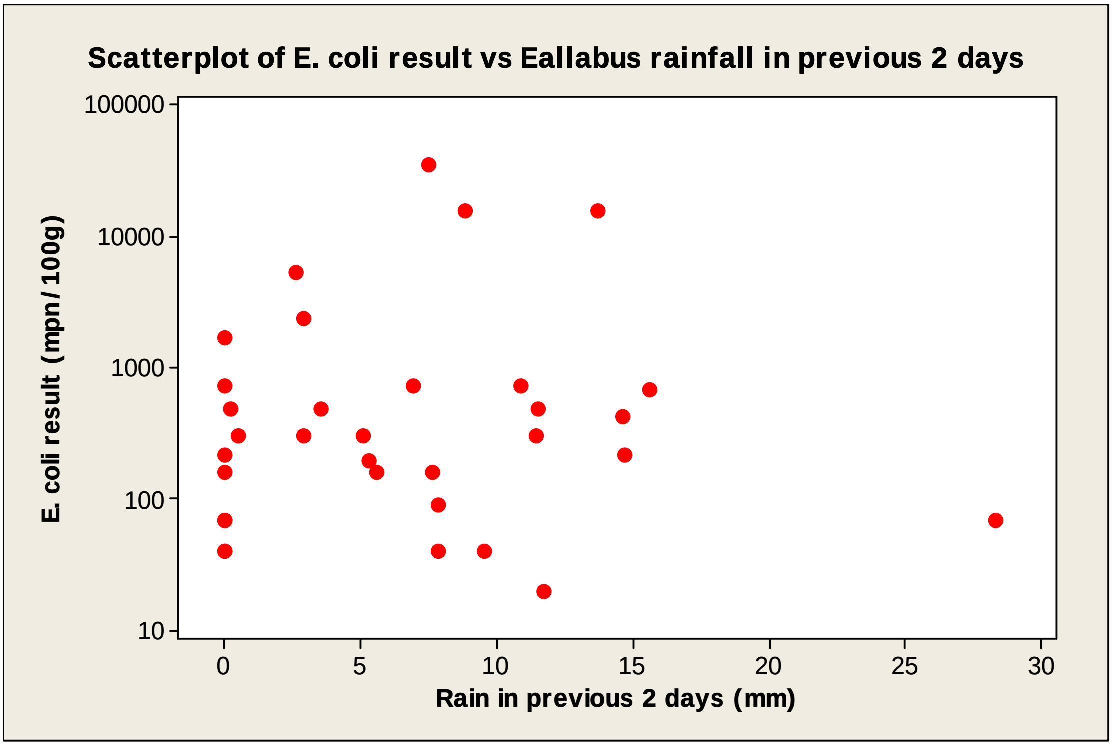


Figure 11.6 Scatterplot of shellfish *E. coli* result against rainfall in previous 2 days

The coefficient of determination indicates that there is no relationship between the *E. coli* result and the rainfall in the previous two days (Adjusted R-sq=0.0%, p=0.862, Appendix 4).

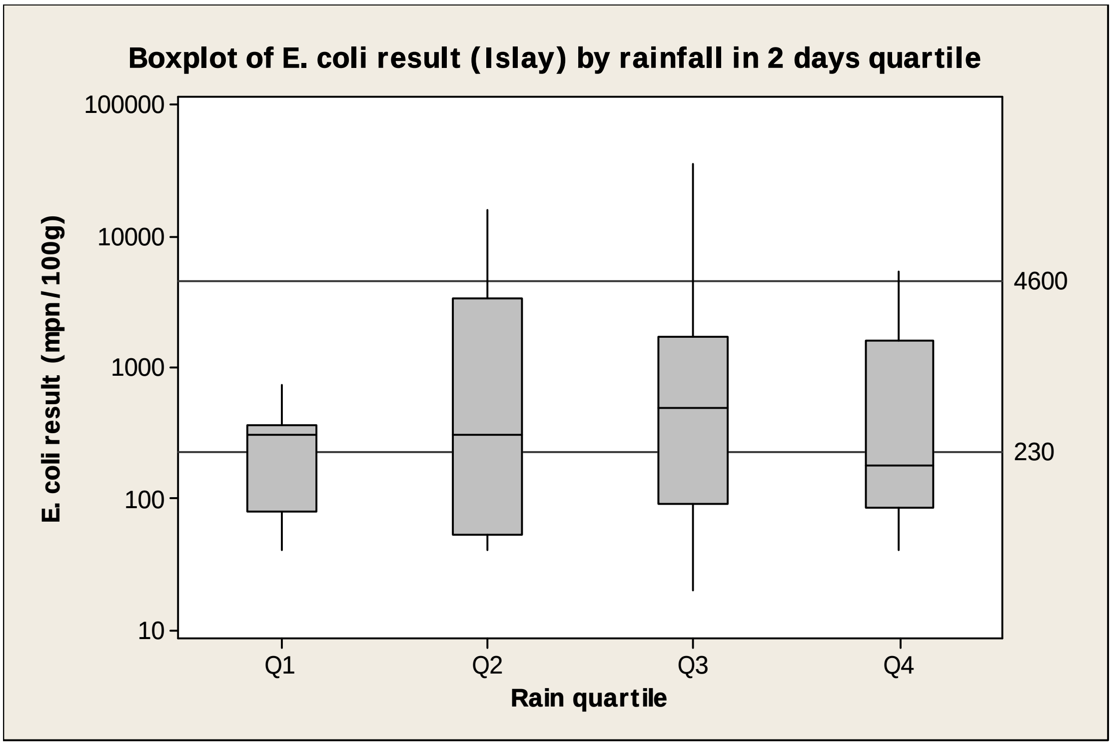


Figure 11.7 Boxplot of shellfish *E. coli* result by rainfall in previous 2 days quartile

No difference between the results for each rain quartile was found (One way ANOVA, p=0.623, Appendix 4) with the highest results occurring for quartile 4 compared to the other quartiles.

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 Islay was investigated in an identical manner to the above. Interquartile ranges for 7 days rainfall were as follows; quartile 1 = 0 to 11.2 mm; quartile 2 = 11.2 to 23.4 mm; quartile 3 = 20.1 to 38.7 mm; quartile 4 = more than 38.7 mm. Rainfall data was only available for 32 of the 63 samples.

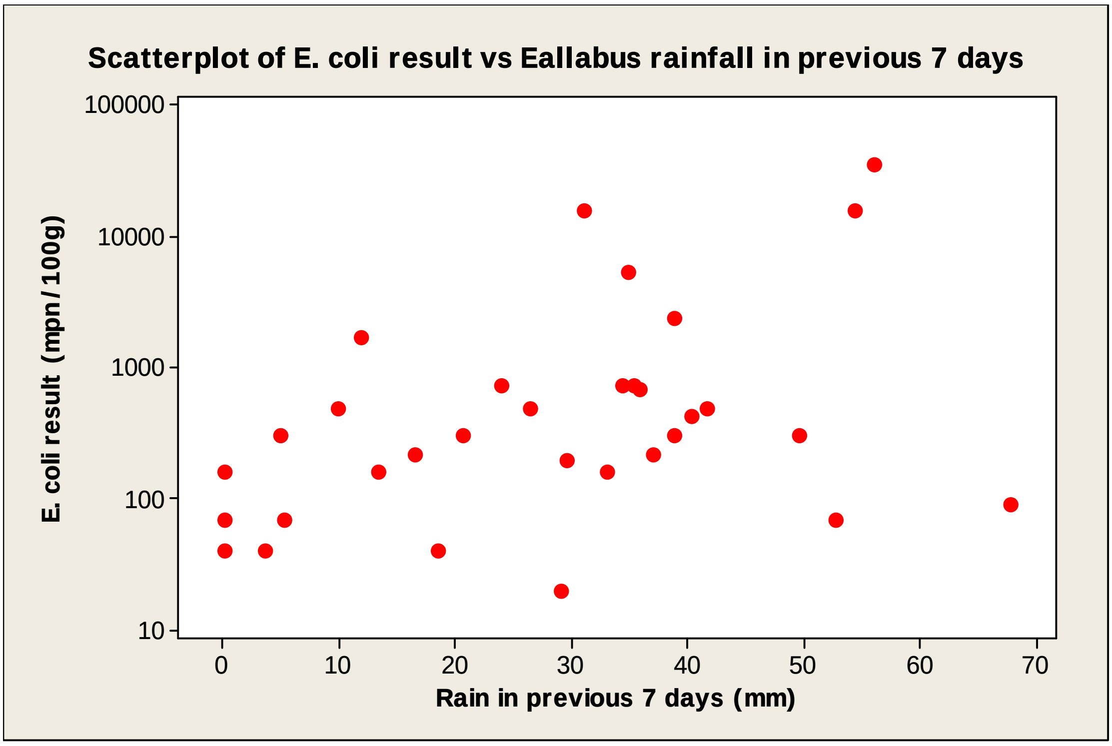


Figure 11.8 Scatterplot of shellfish *E. coli* result against rainfall in previous 7 days

The coefficient of determination indicates that there is a weak positive relationship between the *E. coli* result and the rainfall in the previous seven days (Adjusted R-sq=14.2%, p=0.019, Appendix 4).

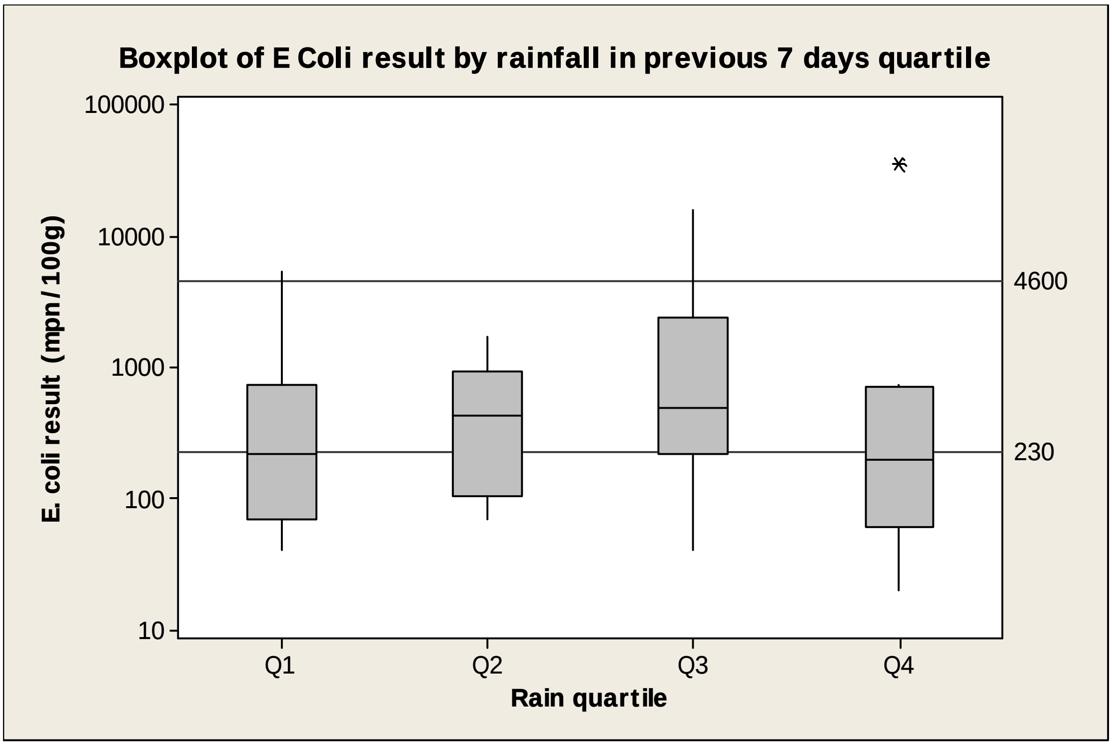


Figure 11.9 Boxplot of shellfish *E. coli* result by rainfall in previous 7 days quartile

No difference between results for each quartile was detected (One way ANOVA, p=0.633, Appendix 4).

Overall, no relationship between *E. coli* result and rainfall in the previous 2 days was detected and only a weak positive relationship between rainfall in the previous 7 days and *E. coli* result was found. The number of samples used in these analyses was small however (33 and 32). The influence of rainfall on microbiological quality will depend on factors such as local geology, topography and land use.

11.4.3 Analysis of results by size of previous tide

With the larger tides, exchange of water in the loch will increase bringing in more uncontaminated water from the open sea. However, more of the shoreline will be covered, potentially washing more faecal contamination from livestock into the loch. Tidal ranges in the loch (as described in section 13) are large, and a high proportion of the water in the loch is exchanged every tidal cycle. Figure 11.10 presents a scatter plot of *E. coli* results against the predicted height of the previous high water at Ardnave Point. Figure 11.11 presents a boxplot of *E. coli* results by categorised the predicted height of the previous high water at Ardnave Point. It should be noted however that local meteorological conditions such as wind strength and direction can influence the height of tides and this is not taken into account in this analysis. It must also be noted that the samples were mainly gathered during larger tides for practical reasons.

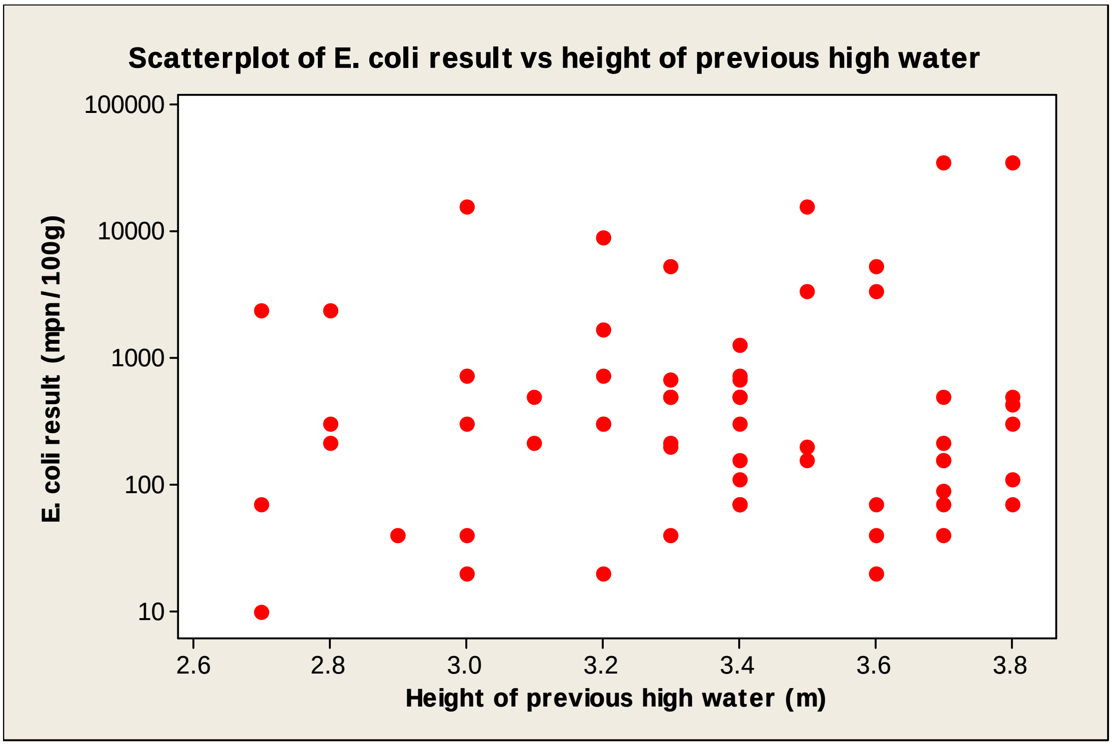


Figure 11.10 Scatterplot of shellfish *E. coli* result by tide size

The coefficient of determination indicates that there is no relationship between the *E. coli* result and the height of the previous tide (Adjusted R-sq=0.0%, p=0.570, Appendix 4).

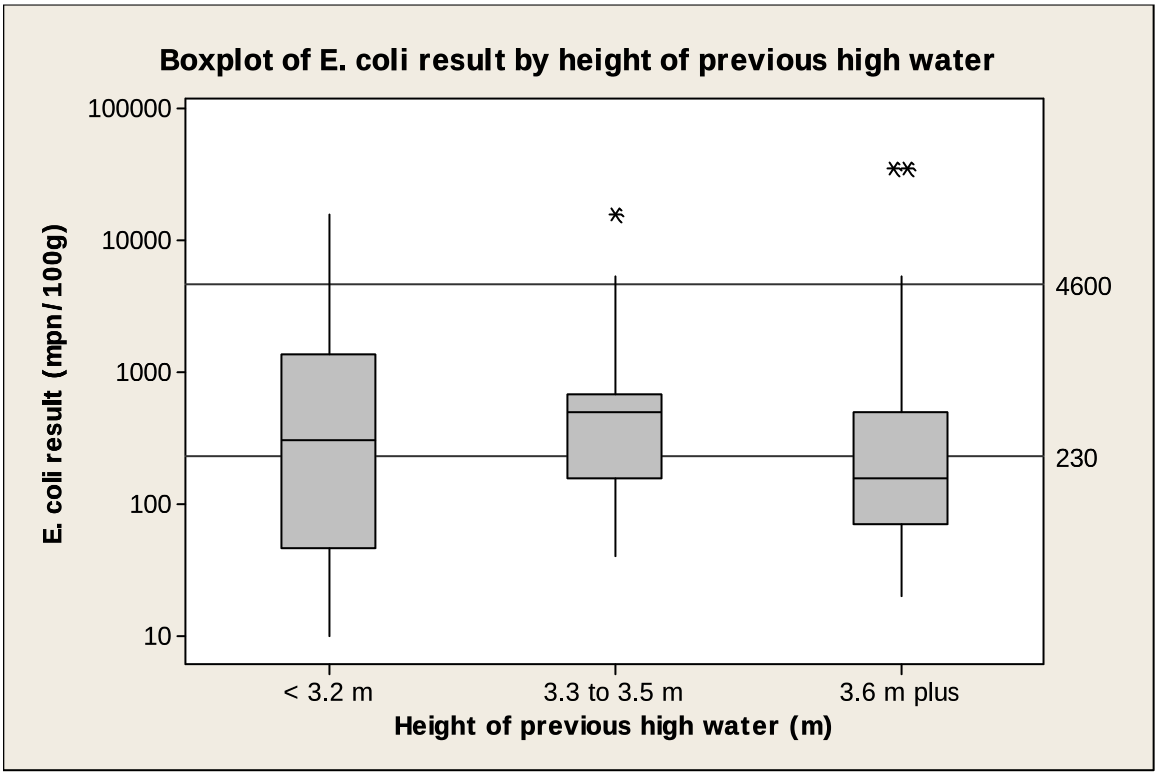


Figure 11.11 Boxplot of shellfish *E. coli* result by tide size

No difference between the results obtained under different tidal height categories was found (One way ANOVA, p=0.900, Appendix 4).

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.

No records of water temperature at the time of sample collection were available prior to 2007, so no analysis is possible.

11.4.5 Wind direction

Wind speed and direction may change water circulation patterns in the Loch. 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 11.12.

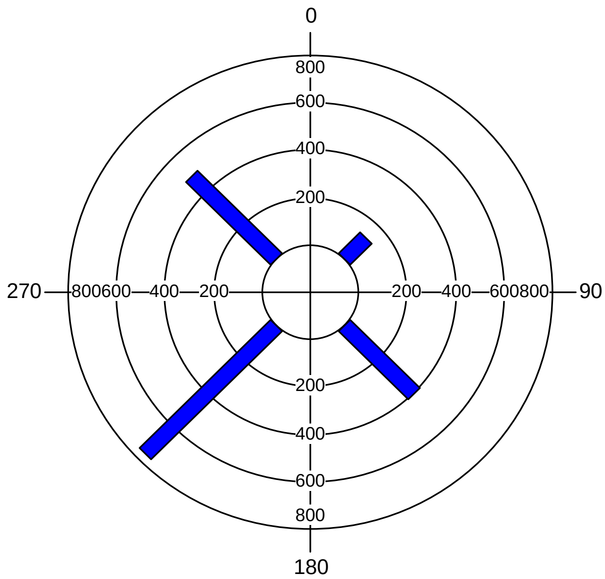


Figure 11.12 Circular histogram of geometric mean *E. coli* result by wind direction

Although Figure 11.12 indicates that higher mean results occurred when the wind was from the south west, no correlation between wind direction and *E. coli* result was found (circular-linear correlation, r=0.27, p=0.279, Appendix 4). It must be noted that this is the prevailing wind direction, and when it is blowing in this direction it is likely to be stronger than when blowing from other directions, and that 17 of the 36 results for which wind data was available were gathered under these conditions.

11.4.6 Discussion of environmental effects

A strong seasonal effect was found, with results in the summer and autumn being significantly higher than in spring and winter. A very weak positive relationship between rainfall in the previous 7 days and results were found, but there was no similar relationship between results and rainfall in the previous two days. No influence of tide size or wind direction was apparent. Summer and autumn are the seasons when livestock densities are at their highest.

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 Islay, as the area had seasonal classifications in 2005 and 2006.

12. Designated Shellfish Growing Waters Data

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

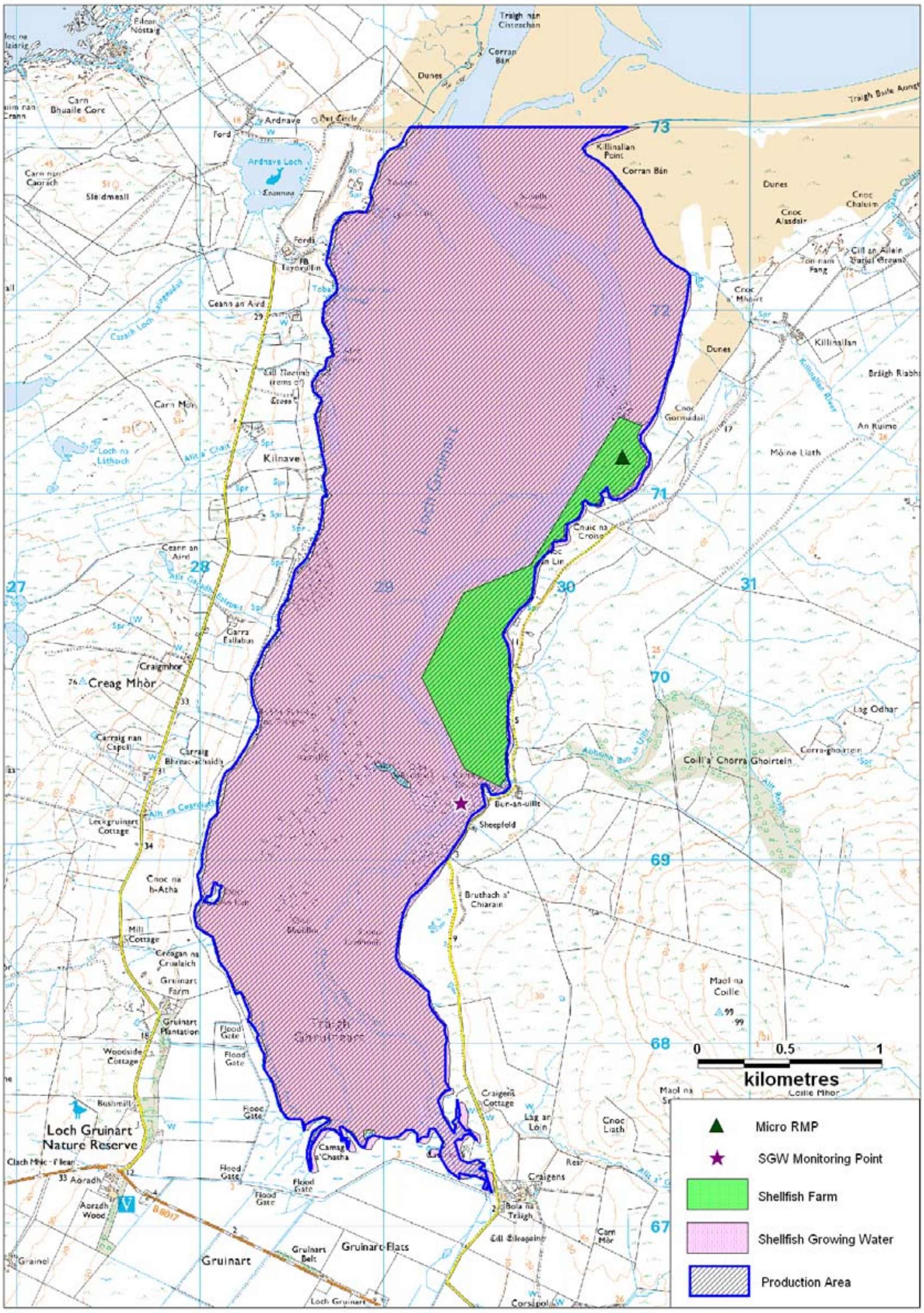


Figure 12.1 SEPA designated growing water and monitoring point

The monitoring regime requires the following testing:

- Quarterly for salinity, dissolved oxygen, pH, temperature, visible oil
- Every third year for metals and organohalogens in mussels, next collection scheduled for 2008
- Quarterly for faecal coliforms in mussels

Monitoring started in 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 (MPN fc /100 g) for shore mussels gathered from Loch Gruinart.

	Site	Loch Gruinart	Loch Gruinart
	NGR	NR 303 712	NR 295 693
	Q1	20	-
	Q2	-	-
	Q3	-	54000
2003	Q4	-	750
	Q1	-	220
	Q2	-	1300
	Q3	-	3450
2004	Q4	-	200
	Q1	-	160
	Q2	-	16000
	Q3	-	17000
2005	Q4	-	1300
	Q1	-	-
	Q2	-	550
	Q3	-	230
2006	Q4	-	390

All but one of these samples were gathered from the southern end of the shellfish farm at the sampling point indicated on Figure 12.1. No detailed analysis of these results was carried out due to the small number of samples taken. The geometric mean result of the samples taken from NGR NR 295693 is 1270 MPN f.c. / 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. Assuming rough equivalence, the level of contamination in shore mussels taken from the current SEPA monitoring point is indicative of high, and intermittently very high, levels of faecal contamination. Results were on average higher than those observed in oysters taken from the RMP, but lower than those observed in oysters taken from the RMP in 2006.

Results of tests for chemical parameters were not considered in this assessment as they do not directly affect the microbiological quality of shellfish.

13. Bathymetry and Hydrodynamics

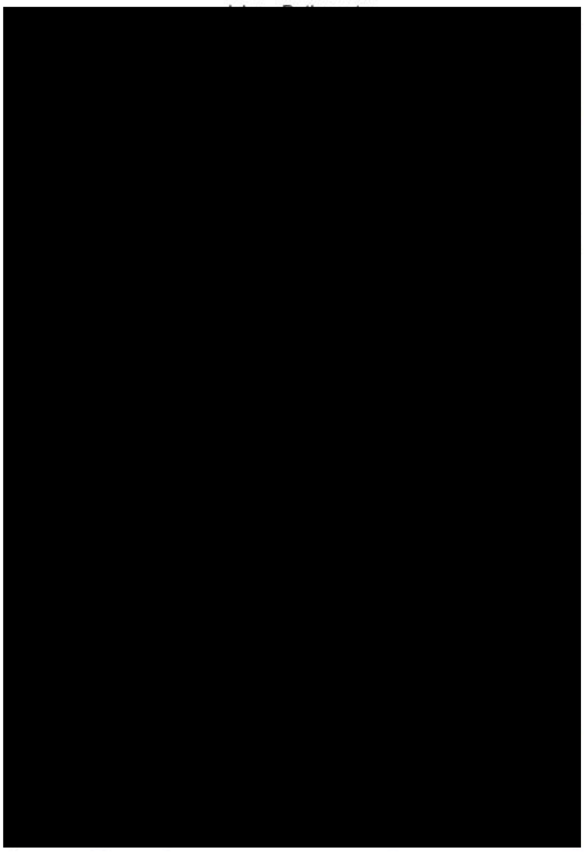


Figure 13.1 Loch Gruinart bathymetry

Figure 13.2 Loch Gruinart shellfish farm

The chart above shows that the depth at the opening of Islay ranges from less than 10m to 50m, with the presence of a drying area covering most of the loch and the shellfish farm. The following characteristics were obtained for Loch Gruinart from the Scottish sea loch catalogue (Edwards and Sharples, 1986).

Length:	6.2 miles
Max depth:	8 metres
Fresh/Tidal flow ratio:	4.3
Salinity reduction:	0.1 ppt
Flushing time:	1 day

13.1 Tidal Curve and Description

The two tidal curves below are for the port of Ardnave Point, which is located on the northwest headland of Islay – they have been output from UKHO TotalTide. The first is for seven days beginning 00.00 GMT on 09/06/07 and the second if for seven days beginning 00.00 GMT on 16/06/07. This two-week period covers the date of which the shoreline survey was undertaken. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle.

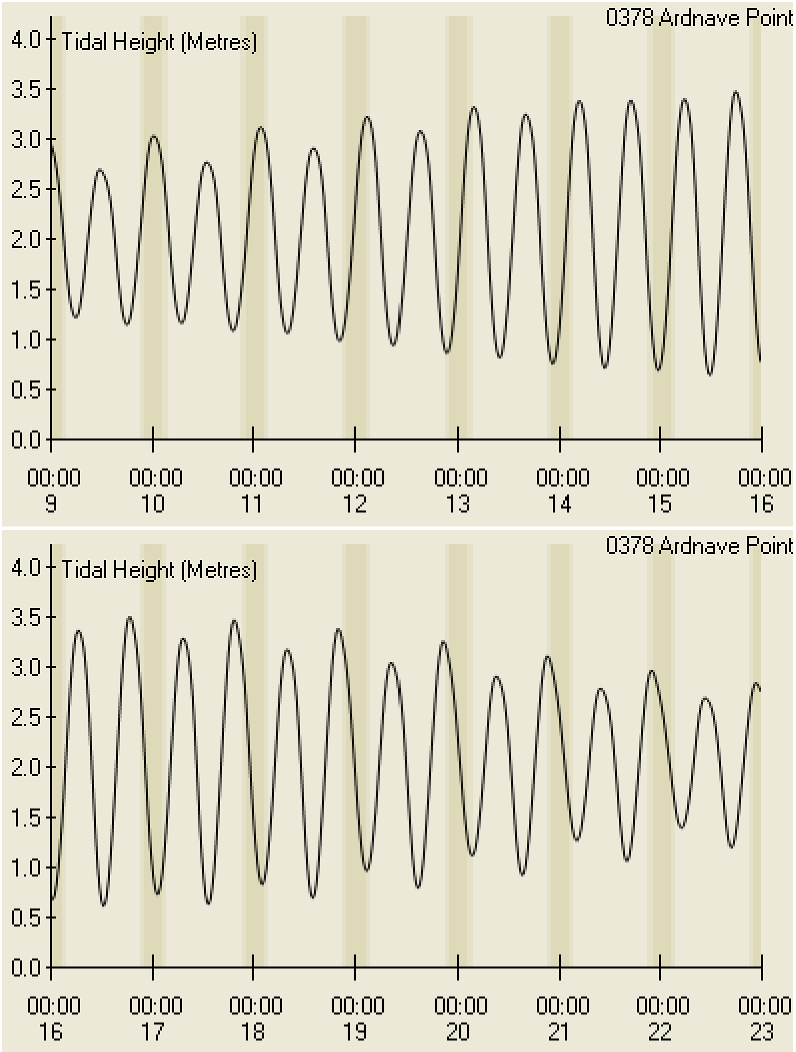


Figure 13.3 Tidal curves for Ardnave Point

The following is the summary description for Ardnave Point from TotalTide:

The tide type is Semi-Diurnal.

MHWS	3.6 m
MHWN	2.7 m
MLWN	1.5 m
MLWS	0.6 m

Predicted heights are in metres above chart datum. The tidal range at spring tide is therefore approximately 3 m and at neap tide 1.2 m.

13.2 Currents – Tidal Stream Software Output and Description

No tidal stream information is available for Loch Gruinart.

Conclusions

Loch Gruinart is an extensive area of sand flats that dry almost completely at low tide. Maximum depth in the non drying area at the mouth of the loch is <10m. Tidal flows are expected to be the most significant factor affecting movement of pollutants, with complete flushing occurring with each tidal cycle.

Livestock graze an area of salt grasses near the head of the loch that would be inundated during the higher tides. This would result in flushing of additional contaminants through the loch at high spring tides.

Contaminants entering the loch via streams to the north and south of the oyster farm would be washed across the trestles on the incoming and outgoing tides, respectively. Contamination from livestock faeces on the shoreline to the east of the oyster farm would impact the farm on the outgoing tide as water retreated to the channel and out the mouth of the loch.

Contaminant sources from the west side of the loch are unlikely to affect the oyster farm on the east side. The exchange of water is such that intermittent contamination is likely to be washed out within a small number of tidal cycles. Contamination within the shellfish, especially of some types of human pathogens, would tend to persist longer than this.

14. River Flow

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

The following burns were measured and sampled during the shoreline survey.

Table 14.1 River flows and loadings –Loch Gruinart

No.	NGR	Description	Width (m)	Depth (m)	Meas. Flow (m/s)	Flow m3/day	*E. coli* (cfu/ 100 ml)	Loading (*E.coli* /day)
1	NR 28325 70301	Stream	0.4	0.03	0.1	100	260	2.7×10^{8}
2	NR 29714 69413	Abhainn Bun an Uillt (Jul)	1.3	0.08	0.3	2695	>10000*	4.0×10^{11}*
3	NR 30707 72153	Killinallan River (Jul)	2	0.03	0.1	500	5200	2.7×10^{10}
4	NR 29704 69399	Abhainn Bun an Uillt (Nov)	3.3	0.22	0.870	55000	200	1.1×10^{11}
5	NR 30980 71941	Killinallan River (Nov)	0.89	0.12	1.221	11000	300	3.4×10^{10}

* A nominal assumed value of 15000 cfu *E. coli*/100 ml was used for calculation of loading.

Two sets of measurements were taken for the larger streams flowing into Loch Gruinart, one in July and the second in November. The difference in flow rates is substantial with much higher flows seen in the November visit. This would tend to dilute contaminants as they flow into the loch. The lower concentrations of *E. coli* found in the November water samples seems to confirm this. However, this may also be due to lower stocking rates and improved farm waste management practices since the July visit.

The Abhainn Bun an Uillt enters the loch nearest the southern end of the fishery and would be a significant source of contaminants for the entire fishery particularly on the outgoing tide. The main growing area of oyster trestles is located at the northern end of the fishery in the vicinity of the RMP.

The Killinallan River flows into Loch Gruinart 0.8 km north east of the edge of the fishery, just over 1 km from the RMP. While this was less contaminated than the Abhainn Bun an Uillt when surveyed in July, it provided nearly double the freshwater input to the loch and so constituted a significant source of contaminants. Though the bacterial concentrations seen in the November samples were much lower than in the July samples, the flow rates were much higher so there was little difference in the overall loadings.

A third stream located along the western shore of the loch was measured and sampled in July. Bacterial loadings from this stream were substantially lower than from the other two.

The Abhainn Bun an Uillt and the Killinallan River are both significant sources of faecal contamination to the fishery, with the Abhainn Bun an Uillt having a higher loading and impacting more subtantially on the southern half of the fishery while the Killinallan would have a greater impact at the northern end.

The locations of the streams in relation to the fishery are shown in Figure 14.1. Streams are labelled with the number assigned in Table 14.1. Loadings are displayed in digital scientific format on the map, where 1E+10 is equal to 1 x 10^{10}.

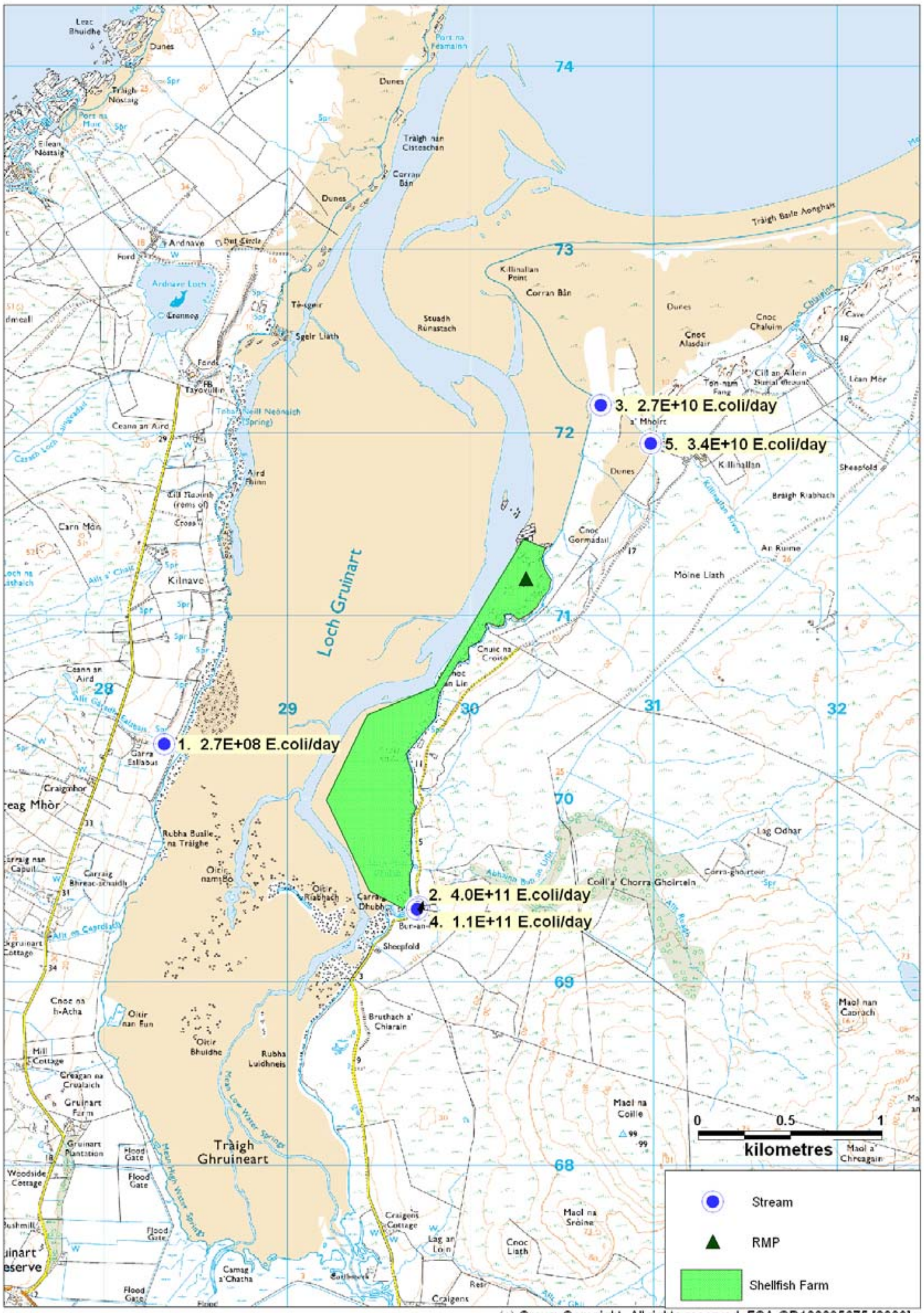


Figure 14.1 Stream loadings into Loch Gruinart

15. Shoreline Survey Overview

The shoreline survey was conducted on 12-13 June and the site was revisited on 22 November 2007.

There was little in the way of human habitation around the loch. Two septic discharges were found during the survey, however it could be assumed that all 21 dwellings observed would be on septic tank systems as there was no mains sewerage. One septic tank outfall serving 3 houses discharges to a stream on the west shore of the loch. The other serves the oyster processing shed and discharges to the stream on the east side of the loch at the southern end of the fishery.

A significant population of seals was observed foraging amongst the oyster trestles and the harvester reported up to 50 could be seen at a time hauled out on the sand approximately 100 metres from the trestles.

Land use around the loch is predominantly sheep or cattle grazing and some ungrazed marsh maintained by the RSPB. There were three farms in the area with approximately 500 cattle and 1800 sheep and lambs. At the time of survey, approximated 400 ewes and lambs were grazing on an area of low-lying grassland at the head of the loch that is inundated at larger high tides. Faecal material left by the grazing animals would be washed into the loch with the outgoing tide. In most areas of the loch livestock had free access to the shoreline as well as to streams flowing into the loch.

High concentrations of *E. coli* were found in samples taken from both these streams during the June survey. Loadings were calculated and the two highest are noted on the map in Figure 15.1. Loading levels were not significantly different between the June and November samples. Though the *E. coli* concentrations were higher in June, the flow levels were greater in November.

Shellfish samples were collected from bags placed a fortnight before hand at the extents of the shellfish farm area and results indicated relatively high levels of contamination across the farm with the highest concentrations found at the northernmost extent of the fishery. Of the five samples collected, three were found to have concentrations in excess of 4600 *E.coli* per 100 g of flesh.

Water samples results showed higher levels of contamination along the eastern shore of the loch compared to the western shore.

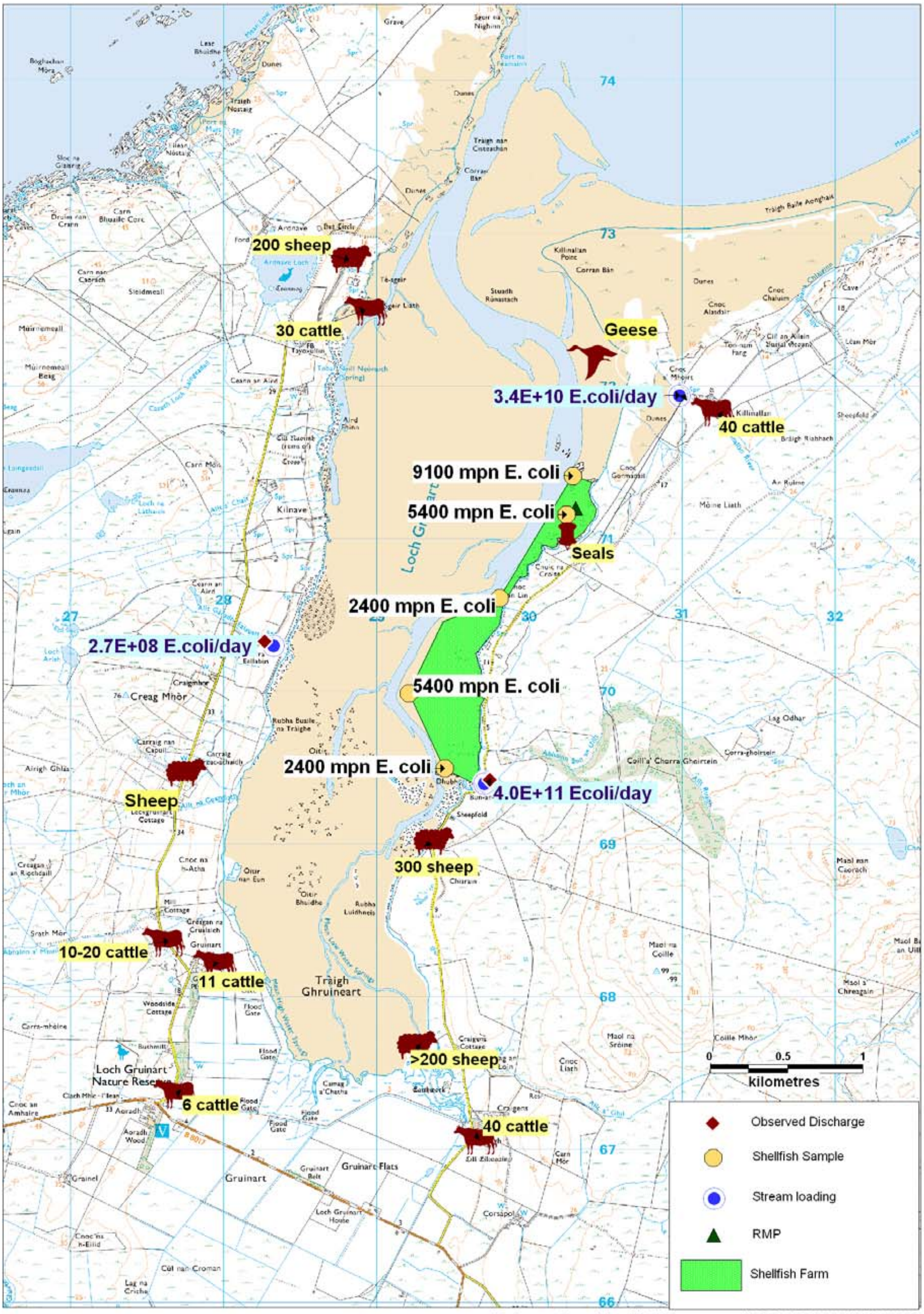


Figure 15.1 Significant findings from the shoreline survey at Loch Gruinart

16. Overall Assessment

Human Sewage Impacts
Loch Gruinart receives little in the way of human sewage. There are no community discharges and only 7 private discharge consents on file with SEPA. Only one of these discharges to water, with the remainder being soakaways. These are located along the western shore of the loch where soil drainage characteristics indicate that soakaway systems should operate effectively if properly maintained. A further two septic tank discharges were observed during the shoreline survey. Both discharge to streams, one on the west side of the loch, and the other on the east side of the loch at the southern end of the fishery.

Loch Gruinart is popular with bird watchers, bringing tourists to the area outside of the normal summer holiday season. However, there is little in the way of accommodation or even human habitation in the immediate area of the loch there is not likely to be a large change in sewage input to the loch during one season over another.

Overall, human sewage impacts to the loch are likely to be small. However, the discharge from the septic tank at the farm located on the eastern shore of the loch would significantly impact the fishery. This tank discharges into Abhainn Bun an Uillt which flows past the southern end of the fishery and showed loadings consistent with high levels of faecal contamination. This source of contamination lies in the closest proximity to oyster trestles of any of the other discharges. Water and shellfish samples collected across the fishery show varying impacts along the 2km length of the oyster farm, with highest shellfish results at the southern and northern extremities of the site.

Agricultural Impacts
The impact of agricultural activity around Loch Gruinart is significant. Large numbers of livestock are raised around the loch, with a reported estimate of 500 cattle and 3800 sheep. Both cattle and sheep were observed on the shoreline and sheep were grazing an area of grassland that was inundated on higher tides, thereby increasing the likelihood of faecal material being washed into the loch on the tide. Large amounts of faecal material were observed on the ground around the loch livestock droppings were observed both on the shoreline and under the oyster trestles. Cattle and sheep access the streams that flow into the eastern shore of the loch for drinking and in hot weather are reported to wade in them, increasing the opportunity for direct faecal contamination of the watercourses and hence the fishery. It was recommended that animals be kept from accessing the watercourses directly in order to protect the fishery from contamination via this route.

Some arable cereals are grown in the area, particularly as habitat and food for birds. Most of the area, however, is unimproved grassland used for grazing.

The greatest impact to the fishery is likely to be in summer, when the livestock population is at its highest due to the presence of lambs and when livestock are more likely to be grazing on the salt grasses and directly accessing watercourses. This seems to be supported by both historical *E.coli* monitoring results and by results seen in samples taken during the shoreline survey.

Wildlife Impacts

Seals are known to forage around the oyster trestles at Loch Gruinart. The harvester has reported up to 50 lying on the sandbank near the oyster farm and this figure agrees with an estimate of approximately 50 animals using the loch by Callan Duck at the Sea Mammal Research Unit. The animals will defecate where they haul out onto the sand as well as in the water whilst foraging. While it is certain that this will have some impact on the fishery, the extent of that impact is difficult to predict and it is not possible at this time to tease out the relative contributions of *E. coli* from livestock waste, seal waste and human sewage.

A large population of geese are present on the loch during the late autumn, with peak numbers occurring in November. While they may rest on the loch near the fishery, during the day they will graze on the surrounding grassland. Geese have been shown to be significant contributors to *E. coli* levels in water. However, the presence of geese on the loch coincides with the lowest *E. coli* results, indicating that they are not a significant source of faecal contamination to the fishery. While other species of bird are present around the loch, population numbers supplied by the RSPB indicate that the lowest numbers of all birds present at the loch occur between June and August. This also indicates that birds do not contribute significantly to the high levels of contamination observed in oysters during the summer.

Seasonal Variation

A strong seasonal component to monitoring results was observed, with significantly higher results occurring in the summer and autumn months. This may coincide with higher visitor numbers at the RSPB reserve, seasonal changes in livestock population and behaviour, and changes in rainfall. During hotter weather, livestock will access streams more frequently to drink and to cool off, thereby increasing the bacterial load to the streams.

Rivers and Streams

Two rivers significantly impact the fishery at Loch Gruinart: The Abhainn Bun an Uillt and the Killinallan River. Both had high loadings on the dates of shoreline survey and these remained consistent between the summer and autumn observations as noted in section 14.

Because the oyster farm is spread along more than 2 km of shoreline with only a small holding area in the southern half and the majority of the oyster production in the northern area, it is possible that the Killinallan River will have a greater impact on the fishery as it discharges closer to the oyster trestles. However, contamination from the Abhainn Bun an Uillt would tend to be swept northward across the fishery on an outgoing tide and may still impact the primary oyster growing area as well as the holding area.

Meteorology and Movement of Contaminants

Rainfall patterns at Islay Eallabus (the nearest rainfall station) show a marked increase in average rainfall beginning in September. An increase in rainfall after a period of drier weather would tend to wash a flush of bacteria from the surrounding land into the loch.

Analysis showed no significant correlation between monitoring results and rainfall in the previous two days and only a weak positive correlation between monitoring results and rainfall in the previous 7 days.

No significant correlation was found between wind data and *E. coli* result. Wind driven currents are not expected to play an important part in the movement of contaminants at this site, though strong winds from the north might increase tide height and therefore increase the amount of faecal material washed into the loch.

A broadly higher level of contamination was seen along the eastern shore of the loch as compared to the western shore. Two streams enter the production area along the eastern shore, both of which showed high levels of *E. coli* contamination during the shoreline survey.

The tidal nature of the loch means that movement of contaminants is likely to be highly tidally influenced, being driven into the loch on the incoming tide and drawn toward the 'central' channel and then out of the loch on the outgoing tide. Given the location of the oyster bed, contaminants from the streams and grazing animals on the adjacent shore would be washed across the trestles on each tide and as a result concentrated in the oysters.

Analysis of Results

Historical shellfish hygiene monitoring results show that until 2003, the number of samples collected in a given year was relatively low and variable. Since 2003, sampling has been done somewhat less than monthly, with between 8 and 12 samples submitted per year. This may have led to better capture of variability in monitoring results. Concentrations of *E.coli* found in shellfish samples from this site were markedly higher from around mid 2004 onward. The reason for this deterioration in results is not clear, as the harvester reported no significant changes in farming or aquaculture practices.

SEPA have reported shellfish growing waters monitoring results from 2003 onward. Monitoring done under the shellfish growing waters program administered by SEPA since 2003 has shown high, and intermittently very high, levels of contamination in shore mussels collected at Loch Gruinart. These samples were collected from the southern end of the shellfish farm. Mussels (*Mytilus* sp) have been shown to concentrate indicator bacteria far more efficiently than the Pacific oysters (*C. gigas*) grown on site and so results from the two species are not directly comparable. However, 23% of the results obtained by SEPA exceeded 4600 *E.coli*/100 g.

Sampling conducted during the shoreline survey in June indicated higher levels of contamination were present along the eastern shore of the loch than along the western shore. Highest concentrations of *E.coli* were found in water sampled from a stream feeding into the loch at Craigens (>10000 cfu/100 ml) and in a brackish sample taken from north of the fishery (>10000 cfu/100 ml). In samples taken in November, the highest levels of contamination were found along the south eastern shore of the loch and in the southern half of the fishery (3000 cfu/100 ml at Craigens). A calculation of loadings from the Abhainn Bun an Uillt and the Killinallan

River indicated that though flow rates were higher in November, the bacterial loads carried were roughly the same.

Of five oyster samples collected during the shoreline survey in June, all but two contained concentrations of *E.coli* in excess of the permitted level of 4600 MPN/100 g for B classification. The remaining two fell within B classification limits.

Overall results indicated high levels of contamination present across the fishery with the most significant sources located near the trestles at the southern end of the oyster fishery and to the north of the main growing area of trestles in the northern end of the fishery.

Movement of contaminants across the fishery on the incoming and outgoing tides spreads the impact across the extend of the fishery, leading to significant levels of contamination throughout with little to distinguish one area of the farm as less impacted than another.

17. Recommendations

The current production area boundaries are given as the area south of a line drawn between NR 2914 7300 and NR 3033 7300 and extending to MHWS.

Levels of contamination found along the eastern side of the loch were lower than those found on the western side, which appeared to be substantially cleaner particularly along its northern section. Therefore it is recommended that the production area represented by results obtained at the RMP be restricted to the more contaminated eastern area containing the current fishery.

A new boundary is recommended to include the full extent of the current farm. Boundaries shall be the area bounded by lines drawn between NR 29550 69350 to NR 29000 69350 to NR 29000 70000 to NR 30000 71470 to 30500 71470 extending to MHWS.

The RMP is recorded as being at NR 303 712. The actual reference currently in use is NR 3024 7116. This is the location of the bag used by the local authority for collecting monthly samples. Survey results show significant inputs of bacterial contaminants coming from either end of the farm and that movement of those contaminants spreads the impact across the farm. As there is no compelling reason to suspect significantly higher levels of contamination at any other point on the farm, it is suggested that the current RMP be retained as that used by the Local Authority. This provides the benefit of maintaining consistency in monitoring from the same point over time. Recommended production area and RMP are mapped in Figure 17.1 overleaf.

No sampling depth is applicable. A sampling tolerance of 10 metres is recommended to allow for sufficient mature stock to be sampled.

Because historical monitoring results have not been stable and seasonal affects have turned up in the analyses, it is recommended that monthly sampling be maintained for this production area.

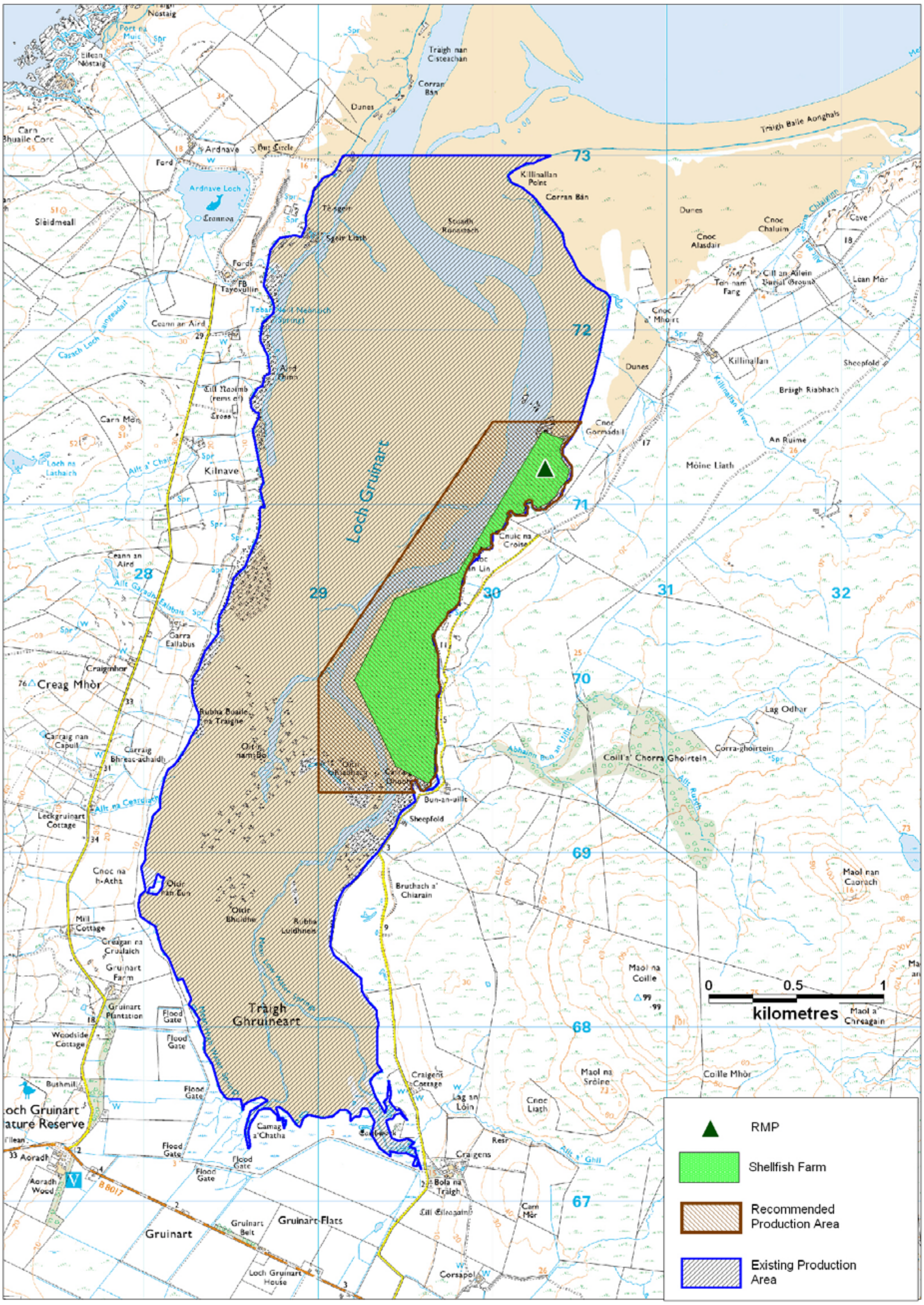


Figure 17.1 Recommendations for Loch Gruinart, Islay

18. References

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19. List of Tables and Figures

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2. Sampling Plan
3. Tables of Typical Faecal Bacteria Concentrations
4. Statistical Data
5. Hydrographic Methods
6. Norovirus Testing Summary

Shoreline Survey Report

Islay
AB 094
Scottish Sanitary Survey Project

Cefas

Shoreline Survey Report

Prod. area:	Islay
Site name:	Loch Gruinart Craigens (AB 904 011 13)
Species:	Pacific Oyster
Harvester:	Mr. Archibald
Local Authority:	Argyll & Bute
Status:	Existing Site
Date Surveyed:	12-13 June 2007, 22 November 2007
Surveyed by:	Christine McLachlan and Alastair Cook
Existing RMP:	NR 30241 71160
Area Surveyed:	See Figure 1.

Weather observations

12-13 June 2007 - Dry, sunny and very warm with negligible winds. No significant rain for at least a week prior to the survey.
22 November 2007 - Occasional showers, Northerly gale.

Site Observations

Specific observations made on site are mapped in Figure 1 and listed in Table 1. Water and shellfish samples were collected at sites marked on Figures 2, 3 and 4. Bacteriology results are presented in Tables 2, 3 and 4. Photographs referenced in Table 1 and the body of the report are presented in Figures 5-22.

Fishery

Pacific oysters are grown in triangular bags on trestles between the eastern shore of the loch and the central channel. The approximate boundary of the farm is indicated on the map as described by the grower on the day of survey. Trestles are mainly concentrated at the north end of the site, but a few of the trestles are kept at the south end of the site next to the processing shed.

Harvesting on site can occur year round, but an important harvest period is in the summer, when oysters are supplied to passing trade and through local festivals and events. Oysters take 2-3 years to reach marketable size.

Human population & sewage inputs

A total of 16 (non-derelict) dwellings were counted on the west shore of the loch, at various distances back from the shoreline. A septic tank overflow was found from one group of 3 houses (Figure 8), and this discharged into a freshwater stream, which in turn discharged into the loch. No other septic discharges were found, although it is unlikely that any of these dwellings were connected to mains sewerage.

A total of 5 (non-derelict) houses were counted on the east shore of the loch. No septic discharges to the loch were found, although again, it is unlikely that any of these dwellings were connected to mains sewerage.

No evidence of sanitary related debris was found anywhere on the shoreline.

Seasonal Population

Discussion with the harvester indicated that most of the houses around the loch were not in year-round occupation.

Boats/Shipping

No boats were observed in the loch at the time of survey. One marker buoy was observed in the channel at on the north east side of the loch although it was unclear what its' purpose was. The loch has no boat landing facilities (jettys etc) and consists of extensive sand flats with a small channel running down the centre at low tide, so is unlikely to experience significant boat traffic.

Land Use and livestock

Land use in the area of surrounding the production area is sheep or cattle grazing aside from an area of ungrazed marsh (Figure 20) on the south western corner of the loch which is part of the RSPB reserve.

There are 3 farms adjacent to the production area. On the east and south sides of the loch is Mr Archibalds' farm which covers an area of around 4500 acres and supports a population of around 200 cows, 1100 ewes and 1200 lambs. To the south and west is a farm owned by the RSPB, which covers an area of around 5000 acres supports about 200 cows and 300 sheep. The farm on the west side of the loch supports about 75-100 cows and 200 sheep. In most areas of the loch, the livestock has free access to the shoreline (e.g. Figure 4 taken on the northwest shoreline, Figure 21 taken on the southeast shoreline).

Of potential significance is the low-lying grassland area at the head of the loch on the eastern side. At the time of survey, about 400 ewes and lambs were grazing on this area, and significant amounts of faecal matter were present on the ground (Figures 10, 11 and 12). This area can be covered with water on larger tides, and it is likely that the ebbing tide will carry this contamination to the oyster trestles. The sheep are removed from the salt marsh area around the 10th September, and are allowed to return from around the 20th October, although they do not frequent the area so much during the winter months, and of course the overall stock size is smaller during the winter.

The growing area has a freshwater stream at either end of the adjacent shoreline, which drain areas of pasture land and moorland higher up. Both these streams were of relatively small size at the time of survey (see Figures 15 and 17), but Mr Archibald reported that following periods of heavy rainfall, the discharge increases greatly from the stream at the southerly end of the trestles, and a plume of turbid water can be observed for several hundred metres along the shoreline. High *E. coli* counts were found in samples taken from both these streams in June. Due to the warm weather preceding and at the time of survey, it is likely that livestock were frequently accessing streams to drink, possibly causing large increases in contamination. Samples were taken a second time during November.

Aside from a septic tank discharging to the stream at the south of the area of trestles and a livestock shed close to the bank of the stream at the north end of the trestles, no other point sources of contamination to these streams was found.

Wildlife/Birds

A few waders and gulls were observed on the shoreline survey but no significant concentrations of birdlife were observed during the course of the survey.

Around high water, at least 10 seals were observed foraging amongst the oyster trestles (Figure 16). A water sample (water sample 11) from this area taken at the same time and place as photo 13 yielded an *E. coli* count of 1900 / 100 ml, the highest result obtained for a salt water sample during the entire survey. At low water when the oyster samples were taken, at least 50 seals were observed resting on a sand bank about 100 m out from the oyster trestles. Mr Archibald confirmed that they often forage amongst the trestles, their numbers vary from 0-100 on any given day, and can be present year round but generally numbers are higher in the summer.

To the east of the loch, the moorland supports a deer population of unknown size. Other wildlife reported in the area includes hares and rabbits.

During the course of the second visit in November 2007 large numbers of geese (several thousand in total, not possible to accurately count) were seen on the exposed sand of the estuary just to the north of the area of trestles just after dawn, and grazing on the fields surrounding the loch later in the day. Significant quantities of droppings were observed on the sand where they had been observed just after dawn.

No seals were noted during the November 2007 visit.

<u>Other observations</u>

The loch drains almost completely at low tide, so the water in the loch is exchanged almost totally each tidal cycle.

Summary

Potential sources of faecal contamination identified during the course of the survey are:

- Seals foraging amongst the trestles.
- Livestock frequenting areas below the tideline (in particular the salt flats at the south of the loch).
- Runoff from the pastures adjacent to the growing area (although no significant rain had been experienced at the site for at least a week prior to the survey).

Acknowledgements

Mr Archibald for his practical support and assistance.

Islay Shoreline Survey

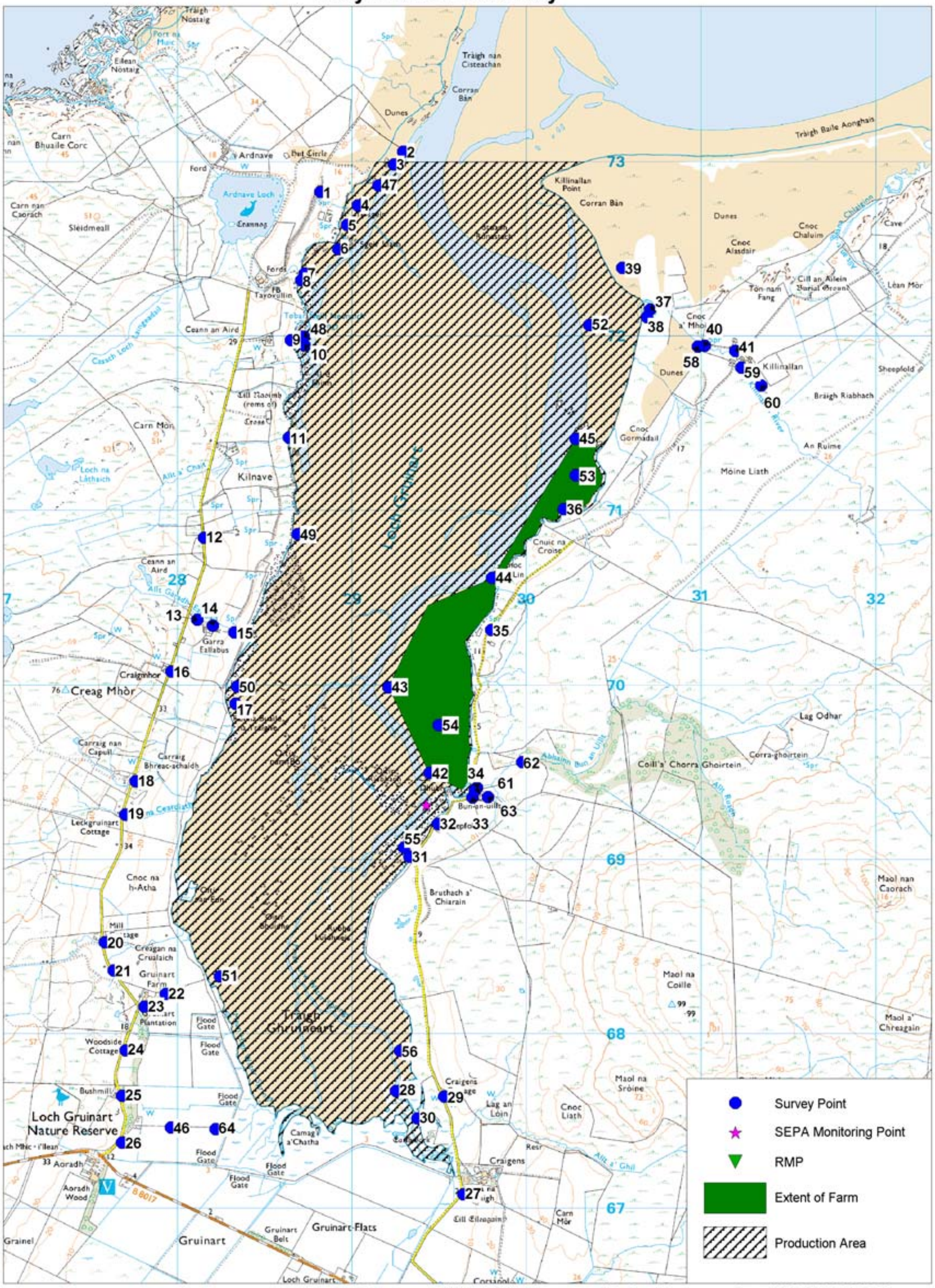


Figure 1. Map of shoreline observations

Table 1. Shoreline observations

No.	Date & time	NGR	East	North	Associated photograph	Description
1	12-JUN-07 10:38:55AM	NR 28818 72829	128818	672829		Field full of 200 sheep, no fence to shore, much excrement on ground
2	12-JUN-07 10:49:42AM	NR 29293 73059	129293	673059		Water sample Islay 1 36ppt
3	12-JUN-07 10:53:47AM	NR 29241 72986	129241	672986		Buoy in channel, purpose uncertain
4	12-JUN-07 10:58:36AM	NR 29032 72752	129032	672752		Very small stream
5	12-JUN-07 11:00:19AM	NR 28970 72640	128970	672640		Abandoned house
6	12-JUN-07 11:03:56AM	NR 28921 72499	128921	672499	Figure 6	30 cows, some on shoreline
7	12-JUN-07 11:09:59AM	NR 28728 72360	128728	672360	Figure 6	Freshwater stream 66x10x0.6 m/s water sample 2. Farm 200m behind shoreline
8	12-JUN-07 11:14:17AM	NR 28708 72323	128708	672323	Figure 7	Rabbit droppings in tideline
9	12-JUN-07 11:21:08AM	NR 28649 71977	128649	671977		Large house, no signs of pipes to shore
10	12-JUN-07 11:27:28AM	NR 28726 71948	128726	671948	Figure 8	Water sample 3
11	12-JUN-07 12:08:47PM	NR 28637 71420	128637	671420		Small stream, water sample 4 (fresh). Abandonded church and house 200m back from shore
12	12-JUN-07 12:19:38PM	NR 28153 70845	128153	670845		Small house observed from road
13	12-JUN-07 12:22:36PM	NR 28114 70374	128114	670374		Approx 100 sheep observed from here
14	12-JUN-07 12:24:14PM	NR 28201 70339	128201	670339	Figure 9	Septic tanks for 3 large houses. Small blue (1.5") plastic overflow pipe discharging ~1L/min into small freshwater stream about 100m back from shoreline.
15	12-JUN-07 12:29:26PM	NR 28325 70301	128325	670301	Figure 10	Water sample 5 (fresh) from stream which septic tank was discharging into. 40cmx3cmx0.1m/s.
16	12-JUN-07 12:41:57PM	NR 27966 70079	127966	670079		2 houses and 200 sheep
17	12-JUN-07 12:51:45PM	NR 28332 69895	128332	669895		Water sample 6 (36ppt)
18	12-JUN-07 1:05:03PM	NR 27759 69451	127759	669451		Sheep on shoreline
19	12-JUN-07 1:06:00PM	NR 27701 69258	127701	669258		House
20	12-JUN-07 1:08:34PM	NR 27583 68527	127583	668527		2 houses
21	12-JUN-07 1:09:34PM	NR 27634 68364	127634	668364		10-20 cattle
22	12-JUN-07 1:12:42PM	NR 27933 68230	127933	668230		10 cows and large bull
23	12-JUN-07 1:14:06PM	NR 27810 68157	127810	668157		Semi abandoned farmhouse
24	12-JUN-07 1:15:09PM	NR 27703 67906	127703	667906		House
25	12-JUN-07 1:16:27PM	NR 27683 67647	127683	667647		Cottages (3) which are RSPB offices
26	12-JUN-07 1:18:17PM	NR 27682 67376	127682	667376		6 cows

No.	Date & time	NGR	East	North	Associated photograph	Description
27	12-JUN-07 1:49:48PM	NR 29637 67081	129637	667081		2 small houses (self catering), 40 cows, farm up hill behind
28	12-JUN-07 2:07:57PM	NR 29251 67674	129251	667674	Figures 11,12 & 13	>200 sheep on saltmarsh, droppings all over an area which is covered on larger tides. Shore not fenced off. Water sample 7 taken from creek.
29	12-JUN-07 2:18:28PM	NR 29528 67641	129528	667641		House
30	12-JUN-07 2:35:52PM	NR 29375 67517	129375	667517	Figure 14	Islay sediment sample 8 (numbered in sequence as if it was a water sample as they were in the same type of pot)
31	12-JUN-07 2:49:27PM	NR 29330 69017	129330	669017	Figure 15	300 more sheep, with access to the shoreline. Water sample 9 36ppt
32	12-JUN-07 3:00:14PM	NR 29490 69206	129490	669206		Very small stream
33	12-JUN-07 3:02:03PM	NR 29690 69356	129690	669356		House and shed
34	12-JUN-07 3:05:06PM	NR 29714 69413	129714	669413	Figure 16	Stream 1.3mx0.8cmx0.3m/s. Water sample 10
35	12-JUN-07 3:35:05PM	NR 29796 70314	129796	670314		Abandoned house. Shoreline still accessible by sheep
36	12-JUN-07 3:47:09PM	NR 30211 71009	130211	671009	Figure 17	At least 10 seals in water around trestles. Water sample 11
37	12-JUN-07 4:13:13PM	NR 30707 72153	130707	672153	Figure 18	Freshwtaer stream 2mx3cmx0.1m/s. Water sample 12
38	12-JUN-07 4:20:53PM	NR 30688 72110	130688	672110		Water sample 13 - water percolating through sand next to stream on beach as tide was rising
39	12-JUN-07 4:37:43PM	NR 30546 72393	130546	672393		Waypoint recorded by accident, no feature of note
40	12-JUN-07 4:50:51PM	NR 31019 71946	131019	671946		40 cows
41	12-JUN-07 4:54:58PM	NR 31195 71916	131195	671916		Abandoned house with barnes which appeared in use
42	12-JUN-07 9:30:44PM	NR 29443 69499	129443	669499		Water sample 14 and Oyster sample 1. Extremity of site.
43	12-JUN-07 9:47:36PM	NR 29209 69988	129209	669988		Water sample 15 and Oyster sample 2. Extremity of site.
44	12-JUN-07 10:06:01PM	NR 29801 70613	129801	670613	Figure 19	Water sample 16 and Oyster sample 3. Extremity of site.
45	12-JUN-07 10:26:02PM	NR 30281 71412	130281	671412	Figure 20	Water sample 17 and Oyster sample 4. Extremity of site. Sheep dropping on sand.
46	13-JUN-07 12:29:35PM	NR 27963 67463	127963	667463	Figure 21	RSPB hide, natural (ungrazed) area of marsh in front
47	22-NOV-07 8:10:00AM	NR 29152 72865	129152	672865		Seawater sample Islay November 1
48	22-NOV-07 8:35:00AM	NR 28723 71998	128723	671998		Seawater sample Islay November 2
49	22-NOV-07 9:00:00AM	NR 28688 70864	128688	670864		Seawater sample Islay November 3
50	22-NOV-07 9:15:00AM	NR 28342 69993	128342	669993		Seawater sample Islay November 4
51	22-NOV-07 9:40:00AM	NR 28243 68331	128243	668331		Seawater sample Islay November 5
52	22-NOV-07 8:11:06AM	NR 30358 72065	130358	672065		Seawater sample Islay November 6. Many geese on sand (perhaps 500 plus).
53	22-NOV-07 8:22:20AM	NR 30280 71202	130280	671202		Seawater sample Islay November 7
54	22-NOV-07 8:36:00AM	NR 29496 69771	129496	669771		Seawater sample Islay November 8

No.	Date & time	NGR	East	North	Associated photograph	Description
55	22-NOV-07 8:46:44AM	NR 29297 69069	129297	669069		Seawater sample Islay November 9
56	22-NOV-07 8:53:44AM	NR 29273 67905	129273	667905		Seawater sample Islay November 10
58	22-NOV-07 10:54:04AM	NR 30980 71941	130980	671941		Stream 89cmx12cmx1.221m/s. Water sample Islay November 11 (fresh).
59	22-NOV-07 11:07:01AM	NR 31228 71821	131228	671821		Livestock shed, cattle in residence.
60	22-NOV-07 11:09:30AM	NR 31342 71717	131342	671717		Water sample Islay 12 November fresh. Rough grazing u/s of here, stream not fenced off.
61	22-NOV-07 11:35:24AM	NR 29704 69399	129704	669399		Stream 330cm wide. Depth and flows measured at 4 points across transect. 24cm (0.091m/s), 19cm (0.251m/s), 17cm (0.419m/s), 26cm (0.435m/s). Water sample Islay November 13.
62	22-NOV-07 11:54:52AM	NR 29974 69560	129974	669560		Water sample Islay 14 November fresh. Upstream of here is bracken and moorland.
63	22-NOV-07 12:03:42PM	NR 29778 69359	129778	669359		Septic tank which reportedly overflows into stream between Water samples 13 and 14.
64	22-NOV-07 12:46:25PM	NR 28219 67455	128219	667455		Water sample Islay November 15 taken from standing water in RSPB marsh.

Table 2. Water sample results

No.	Date	Sample ID	Type	NGR	*E. Coli* (cfu/100ml)	Calculated salinity (g NaCl/L)
1	12/06/2007	Water sample 1	Sea	NR 29293 73059	10	32.0
2	12/06/2007	Water sample 2	Fresh	NR 28728 72360	190	0.1
3	12/06/2007	Water sample 3	Sea	NR 28726 71948	<10	32.1
4	12/06/2007	Water sample 4	Fresh	NR 28637 71420	720	0.1
5	12/06/2007	Water sample 5	Fresh	NR 28325 70301	260	0.1
6	12/06/2007	Water sample 6	Sea	NR 28332 69895	70	29.3
7	12/06/2007	Water sample 7	Sea	NR 29251 67674	7200	5.2
8	12/06/2007	Water sample 9	Sea	NR 29330 69017	360	32.5
9	12/06/2007	Water sample 10	Fresh	NR 29714 69413	>10000	0.1
10	12/06/2007	Water sample 11	Sea	NR 30211 71009	1900	32.0
11	12/06/2007	Water sample 12	Fresh	NR 30707 72153	5200	0.2
12	12/06/2007	Water sample 13	Sea	NR 30688 72110	>10000	16.2
13	12/06/2007	Water sample 14	Sea	NR 29443 69499	230	31.0
14	12/06/2007	Water sample 15	Sea	NR 29209 69988	60	32.1
15	12/06/2007	Water sample 16	Sea	NR 29801 70613	190	32.3
16	12/06/2007	Water sample 17	Sea	NR 30281 71412	60	32.0
17	22/11/2007	Water November 1	Sea	NR 29152 72865	19	36.1
18	22/11/2007	Water November 2	Sea	NR 28723 71998	130	35.6
19	22/11/2007	Water November 3	Sea	NR 28688 70864	120	33.4
20	22/11/2007	Water November 4	Sea	NR 28342 69993	50	32.9
21	22/11/2007	Water November 5	Sea	NR 28243 68331	120	1.5
22	22/11/2007	Water November 6	Sea	NR 30358 72065	20	34.1
23	22/11/2007	Water November 7	Sea	NR 30280 71202	30	33.6
24	22/11/2007	Water November 8	Sea	NR 29496 69771	500	28.2
25	22/11/2007	Water November 9	Sea	NR 29297 69069	700	27.6
26	22/11/2007	Water November 10	Sea	NR 29273 67905	3000	7.1
27	22/11/2007	Water November 11	Fresh	NR 30980 71941	300	Not tested
28	22/11/2007	Water November 12	Fresh	NR 31342 71717	<100	Not tested
29	22/11/2007	Water November 13	Fresh	NR 29704 69399	200	Not tested
30	22/11/2007	Water November 14	Fresh	NR 29974 69560	<100	Not tested
31	22/11/2007	Water November 15	Fresh	NR 28219 67455	30	0.1

Table 3. Sediment sample result

No.	**Date**	**Sample**	**NGR**	***E. coli* (cfu/g)**
1	12/6/07	Sediment sample 8	NR 29375 67517	30

Table 4. Shellfish sample results

No.	Date	Sample ID	Type	NGR	*E. coli* (mpn/100g)
1	12/06/2007	Sample 1	Oyster	NR 29443 69499	2400
2	12/06/2007	Sample 2	Oyster	NR 29209 69988	5400
3	12/06/2007	Sample 3	Oyster	NR 29801 70613	2400
4	12/06/2007	Sample 4	Oyster	NR 30281 71412	9100
5	12/06/2007	Sample 5	Oyster	NR 30241 71160	5400

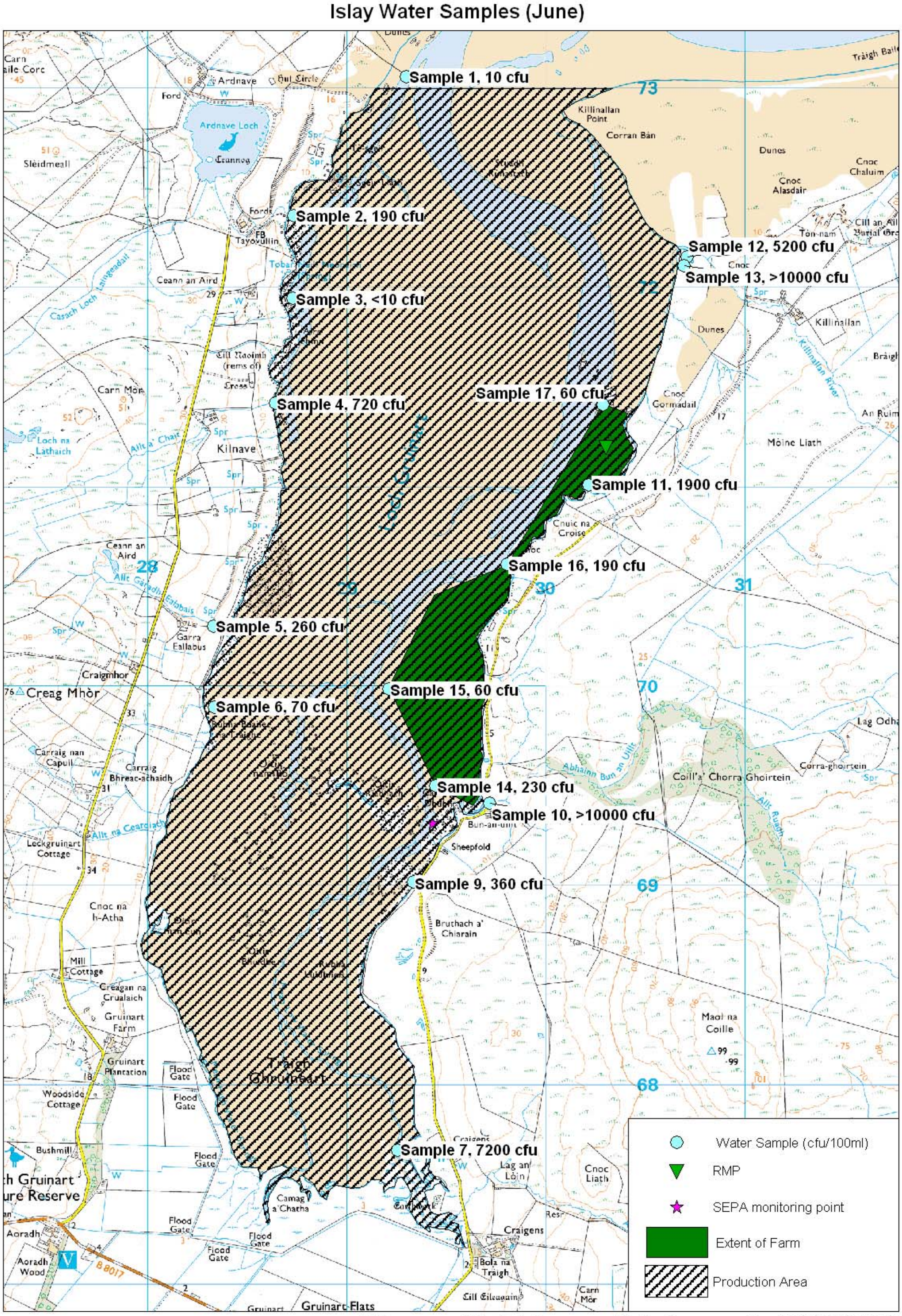


Figure 2. Map of water sample results (June)

Islay Water Samples (November)

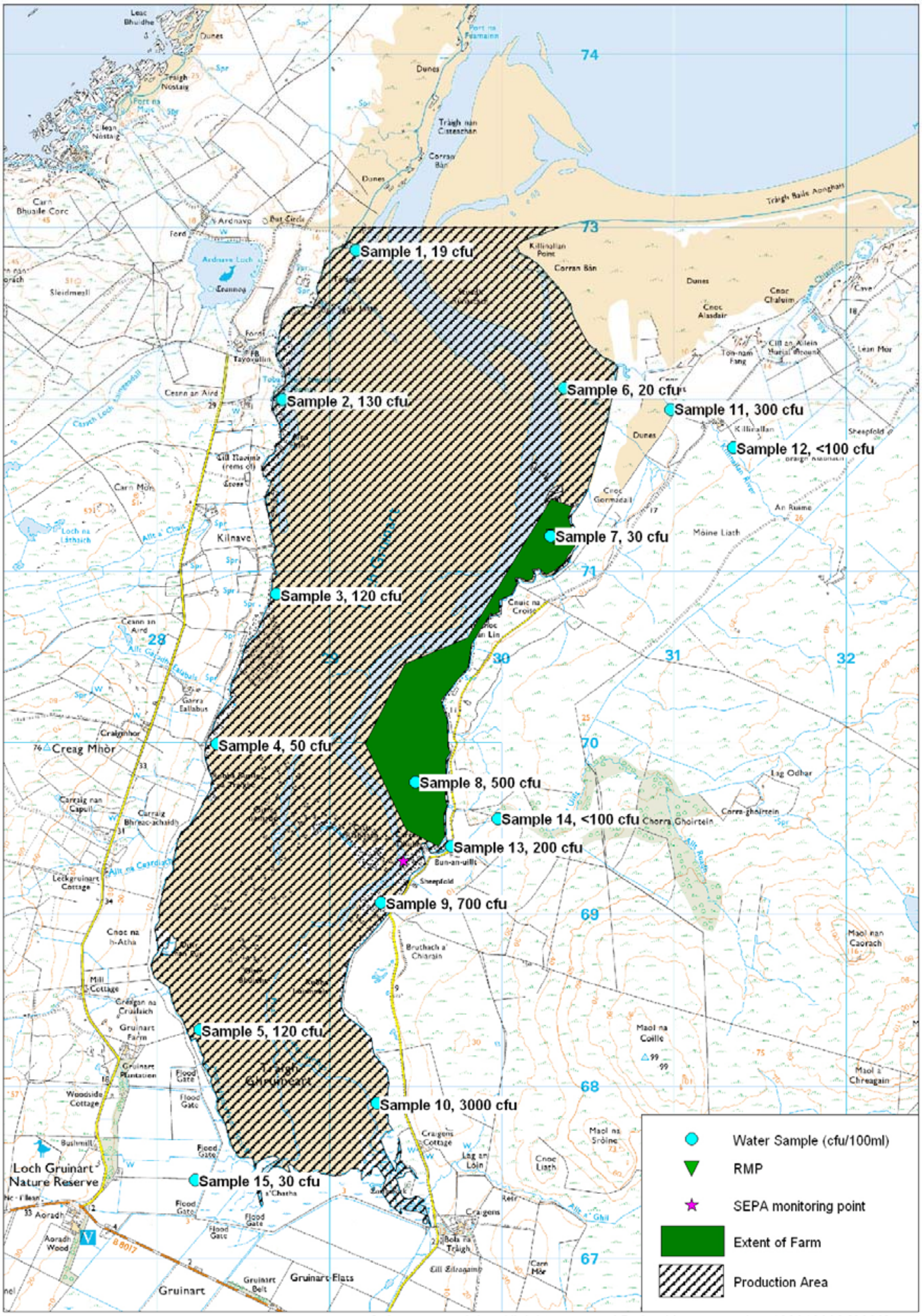


Figure 3. Map of water sample results (November)

Islay Shellfish Samples

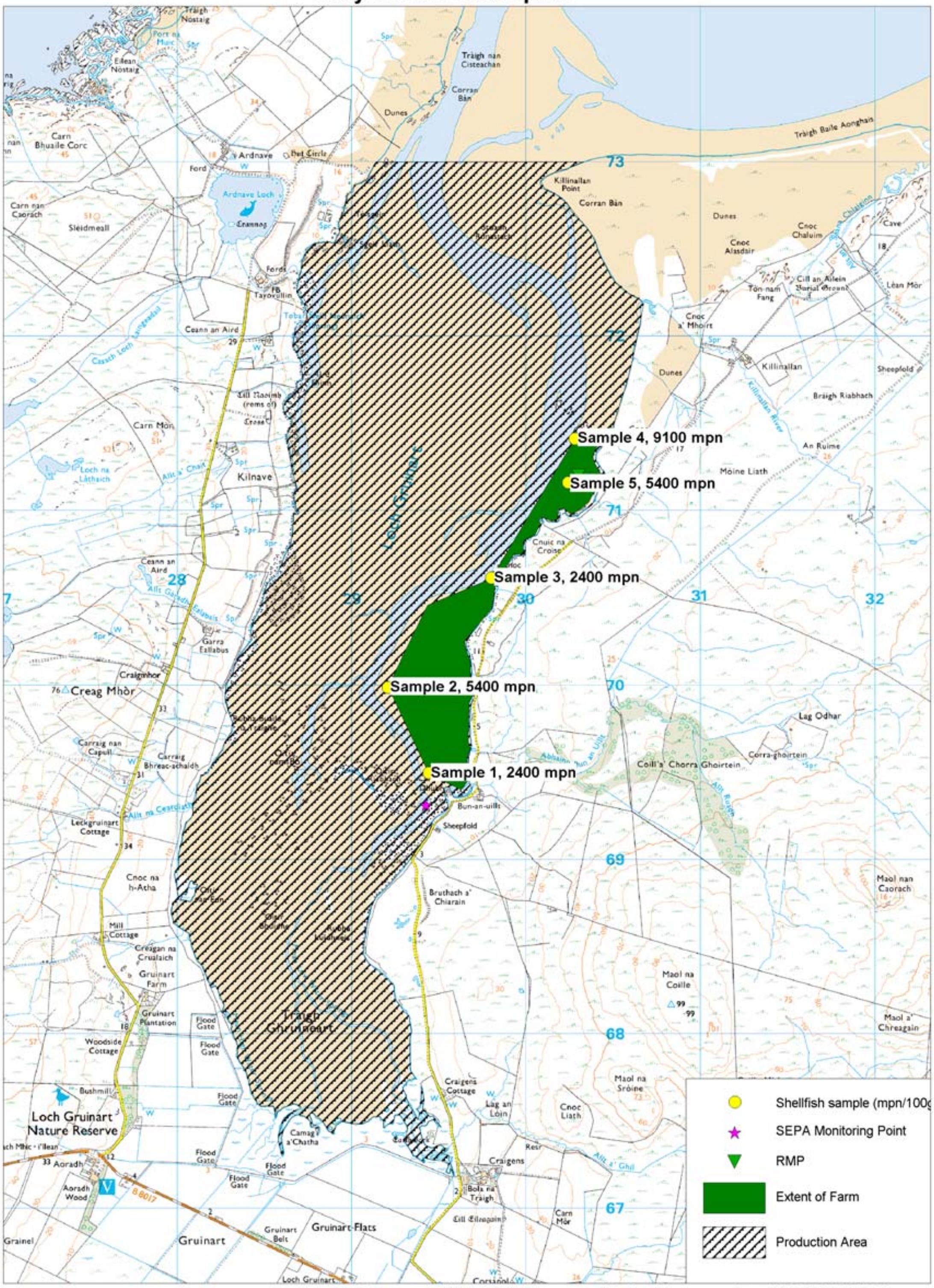


Figure 4. Map of oyster sample results

Photographs

Figure 5. Cow on shoreline

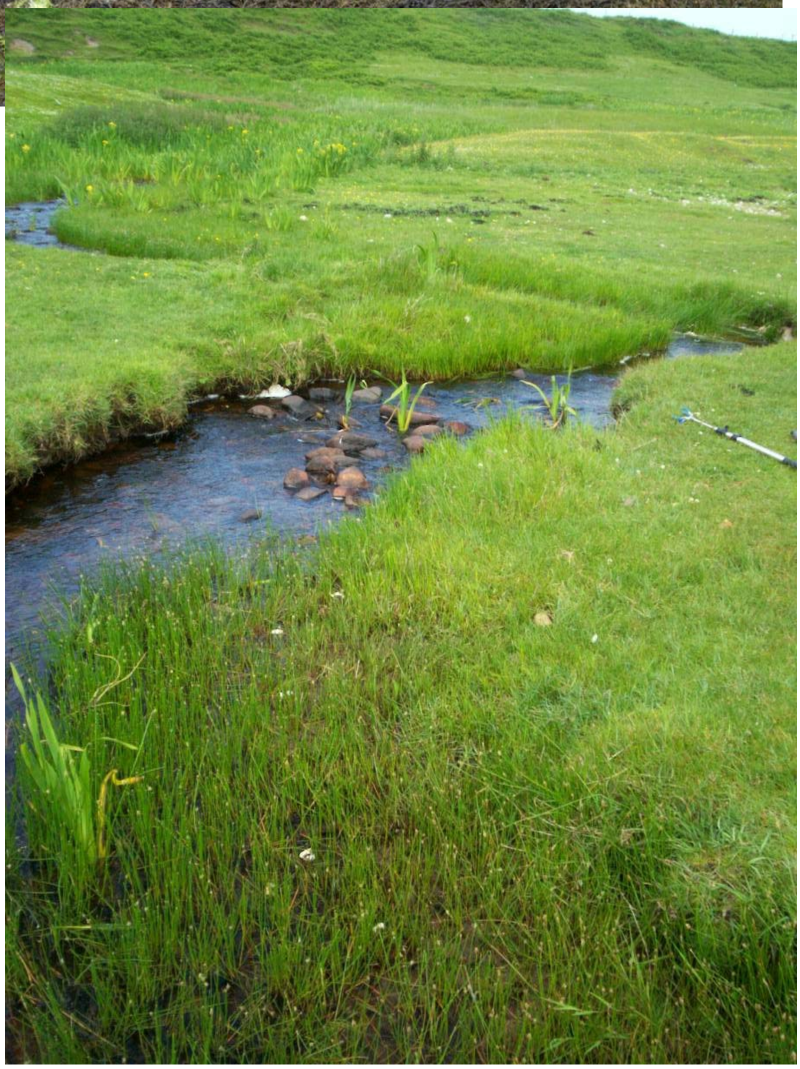


Figure 6. Small stream on west shore

Figure 7. Animal droppings in tideline

Figure 8. Collection of water sample 3

Figure 9. Septic tank on west shore

Figure 10. Stream on west shore

Figure 11. Sheep on south east shore

Figure 12. Sheep tracks and dung on south east shore

Figure 13. Sheep dung in and below the high water mark on the south east shore

Figure 14. Collection of sediment sample from south east shore

Figure 15. Collection of water sample from east shore

Figure 16. Stream at southern end of trestles

Figure 17. Seals around trestles

Figure 18. Stream at northern end of trestles

Figure 19. Trestles exposed at low tide

Figure 20. Sheep dung washed up among trestles at low tide

Figure 21. RSPB reserve on south west shore

Figure 22. Sheep on east shore

Sampling Plan for Loch Gruinart - Islay

PRODUC-TION AREA	SITE NAME	SIN	SPECIES	TYPE OF FISHERY	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
Islay	Loch Gruinart Craigens	AB 094 011 13	Pacific Oyster	Trestle	NR 3024 7116	13024	67116	10	N/A	Hand	Monthly	Argyll & Bute Council	Christine McLachlan William MacQuarrie Ewan McDougall Donald Campbell	Christine McLachlan

Tables of Typical Faecal Bacteria Concentrations

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

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

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

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

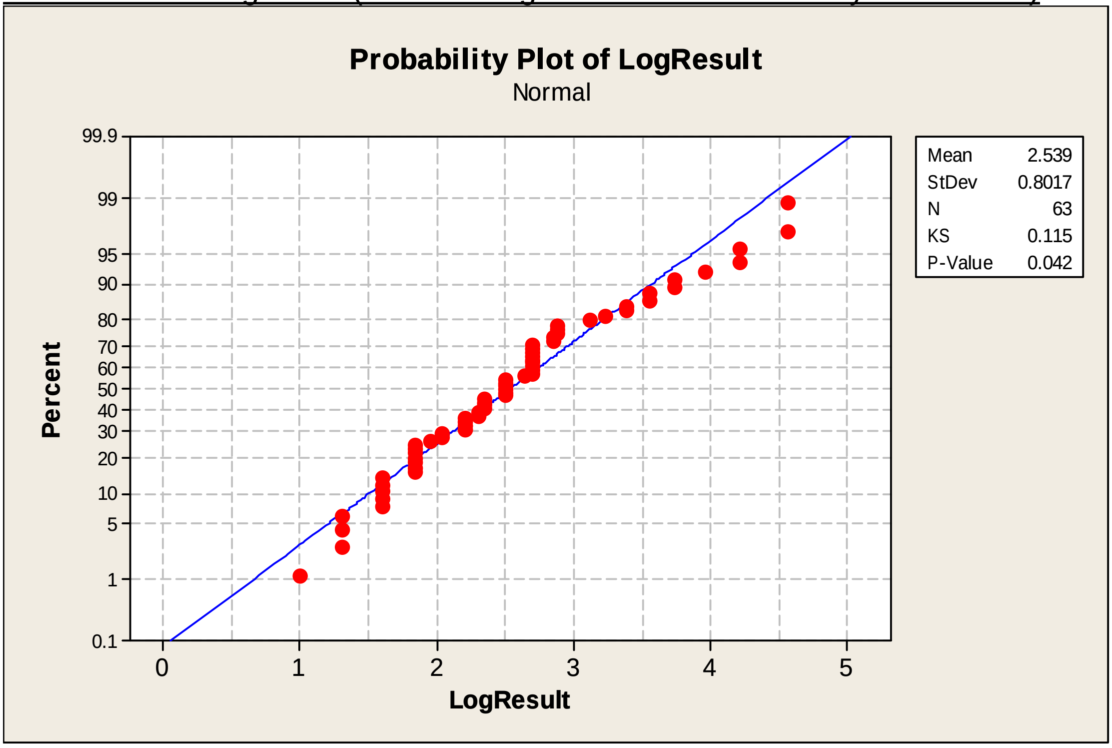
Animal	Faecal coliforms (FC) number	Excretion (g/day)	FC Load (numbers /day)
Chicken	1,300,000	182	2.3×10^8
Cow	230,000	23,600	5.4×10^9
Duck	33,000,000	336	1.1×10^{10}
Horse	12,600	20,000	2.5×10^8
Pig	3,300,000	2,700	8.9×10^8
Sheep	16,000,000	1,130	1.8×10^{10}
Turkey	290,000	448	1.3×10^8
Human	13,000,000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

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

Statistical Data

All analyses were undertaken using log transformed results (aside from the circular linear correlation) as this gives a more normal distribution.

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



Section 11.4.1 ANOVA comparison of results by season

```
Source  DF      SS     MS     F      P
Season   3  10.951  3.650  7.45  0.000
Error   59  28.901  0.490
Total   62  39.852

S = 0.6999   R-Sq = 27.48%   R-Sq(adj) = 23.79%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  --+---------+---------+---------+-------
1      15  2.1261  0.8849         (-------*------)
2      20  2.9540  0.6632                            (-----*-----)
3      19  2.7493  0.6976                        (-----*-----)
4       9  1.8634  0.3202  (--------*---------)
                           --+---------+---------+---------+-------
                           1.50      2.00      2.50      3.00

Pooled StDev = 0.6999


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        0.1957   0.8279  1.4601                     (-----*------)
3       -0.0161   0.6232  1.2625                   (-----*------)
4       -1.0431  -0.2627  0.5177         (------*-------)
                                  --------+---------+---------+---------+-
                                       -1.0       0.0       1.0       2.0


Season = 2 subtracted from:

Season    Lower   Center    Upper  --------+---------+---------+---------+-
3       -0.7977  -0.2047   0.3883           (-----*-----)
4       -1.8336  -1.0906  -0.3477  (------*-------)
                                   --------+---------+---------+---------+-
                                        -1.0       0.0       1.0       2.0


Season = 3 subtracted from:

Season    Lower   Center    Upper  --------+---------+---------+---------+-
4       -1.6349  -0.8859  -0.1370    (------*-------)
                                   --------+---------+---------+---------+-
                                        -1.0       0.0       1.0       2.0
```

Section 11.4.2 Regression analysis (log Result versus rain in previous 2 days).

```
The regression equation is
ResultIE2days = 2.53 + 0.0039 RainIE2days


Predictor       Coef  SE Coef      T      P
Constant      2.5283   0.2015  12.54  0.000
RainIE2days  0.00386  0.02207   0.17  0.862


S = 0.803740   R-Sq = 0.1%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.0197  0.0197  0.03  0.862
Residual Error  31  20.0259  0.6460
Total           32  20.0457


Unusual Observations

Obs  RainIE2days  ResultIE2days    Fit  SE Fit  Residual  St Resid
 19          7.5          4.556  2.557   0.141     1.999      2.53R
 23          8.8          4.204  2.562   0.148     1.642      2.08R
 29         13.7          4.204  2.581   0.211     1.623      2.09R
 33         28.3          1.845  2.637   0.500    -0.792     -1.26 X

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

Section 11.4.2 ANOVA comparison of log Result versus rainfall quartile (previous 2 days).

```
Source  DF      SS     MS     F      P
RQ2D     3   1.163  0.388  0.60  0.623
Error   29  18.883  0.651
Total   32  20.046
```

```
S = 0.8069   R-Sq = 5.80%   R-Sq(adj) = 0.00%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  ------+---------+---------+---------+---
Q1      9  2.3037  0.4383  (-------------*------------)
Q2      5  2.5975  1.0260    (------------------*-----------------)
Q3     11  2.7802  0.9671             (------------*-----------)
Q4      8  2.4960  0.7351      (-------------*--------------)
                           ------+---------+---------+---------+---
                               2.00      2.40      2.80      3.20

Pooled StDev = 0.8069
```

Section 11.4.2 Regression analysis (log Result versus rain in previous 7 days).

```
The regression equation is
ResultIE7days = 3.5 + 9.47 RainIE7days


Predictor      Coef  SE Coef     T      P
Constant       3.51    10.30  0.34  0.735
RainIE7days   9.473    3.821  2.48  0.019


S = 16.7049   R-Sq = 17.0%   R-Sq(adj) = 14.2%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   1715.1  1715.1  6.15  0.019
Residual Error  30   8371.7   279.1
Total           31  10086.8


Unusual Observations

Obs  RainIE7days  ResultIE7days    Fit  SE Fit  Residual  St Resid
 31         4.56          56.00  46.68    8.10      9.32      0.64 X
 32         1.95          67.70  22.03    3.81     45.67      2.81R

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

Section 11.4.2 ANOVA comparison of log Result versus rainfall quartile (previous 7 days).

```
Source  DF      SS     MS     F      P
RQ7D     3   1.119  0.373  0.58  0.633
Error   28  17.993  0.643
Total   31  19.112

S = 0.8016   R-Sq = 5.85%   R-Sq(adj) = 0.00%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  ------+---------+---------+---------+---
Q1      7  2.3905  0.7376  (---------------*--------------)
Q2      5  2.5224  0.5256   (-----------------*-----------------)
Q3     11  2.8357  0.8051               (-----------*-----------)
Q4      9  2.4589  0.9448      (------------*-------------)
```

```
                                ------+---------+---------+---------+---
                                    2.00      2.40      2.80      3.20

Pooled StDev = 0.8016
```

Section 11.4.3 Regression analysis (log Result versus height of previous tide).

```
The regression equation is
Log = 1.90 + 0.190 tide size


Predictor    Coef  SE Coef     T      P
Constant    1.903    1.119  1.70  0.094
tide size  0.1897   0.3320  0.57  0.570


S = 0.806122   R-Sq = 0.5%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.2123  0.2123  0.33  0.570
Residual Error  61  39.6398  0.6498
Total           62  39.8521


Unusual Observations

     tide
Obs  size    Log    Fit  SE Fit  Residual  St Resid
 12  3.00  4.204  2.472   0.156     1.732     2.19R
 43  3.50  4.204  2.567   0.112     1.637     2.05R
 56  3.70  4.556  2.605   0.153     1.952     2.47R
 61  3.80  4.556  2.624   0.179     1.933     2.46R

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

Section 11.4.3 ANOVA comparison of results by height of previous tide

```
Source              DF      SS     MS     F      P
Tide size category   2   0.140  0.070  0.11  0.900
Error               60  39.712  0.662
Total               62  39.852

S = 0.8136   R-Sq = 0.35%   R-Sq(adj) = 0.00%


                                  Individual 95% CIs For Mean Based on
                                  Pooled StDev
Level          N    Mean   StDev  ---+---------+---------+---------+------
< 3.2 m       20  2.4952  0.8782  (-----------------*-----------------)
3.3 to 3.5 m  24  2.5990  0.6204        (----------------*----------------)
3.6 m plus    19  2.5105  0.9488  (------------------*-----------------)
                                  ---+---------+---------+---------+------
                                   2.20      2.40      2.60      2.80

Pooled StDev = 0.8136
```

Section 11.4.5 Circular-linear correlation of wind direction and result

CIRCULAR-LINEAR CORRELATION
Islay
Analysis begun: 19 December 2007 12:58:02

Variables (& observations)	r	p
Angles & Linear (36)	0.27	0.279

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.

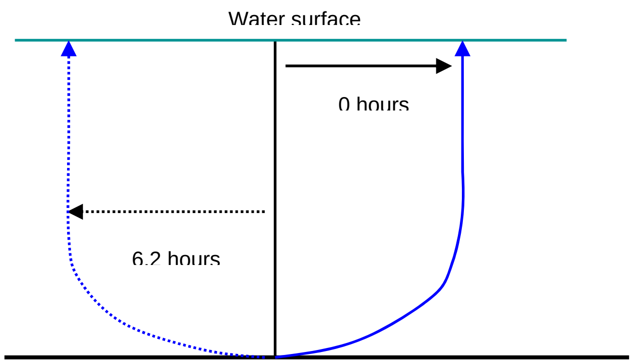
Background processes

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

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

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

a)



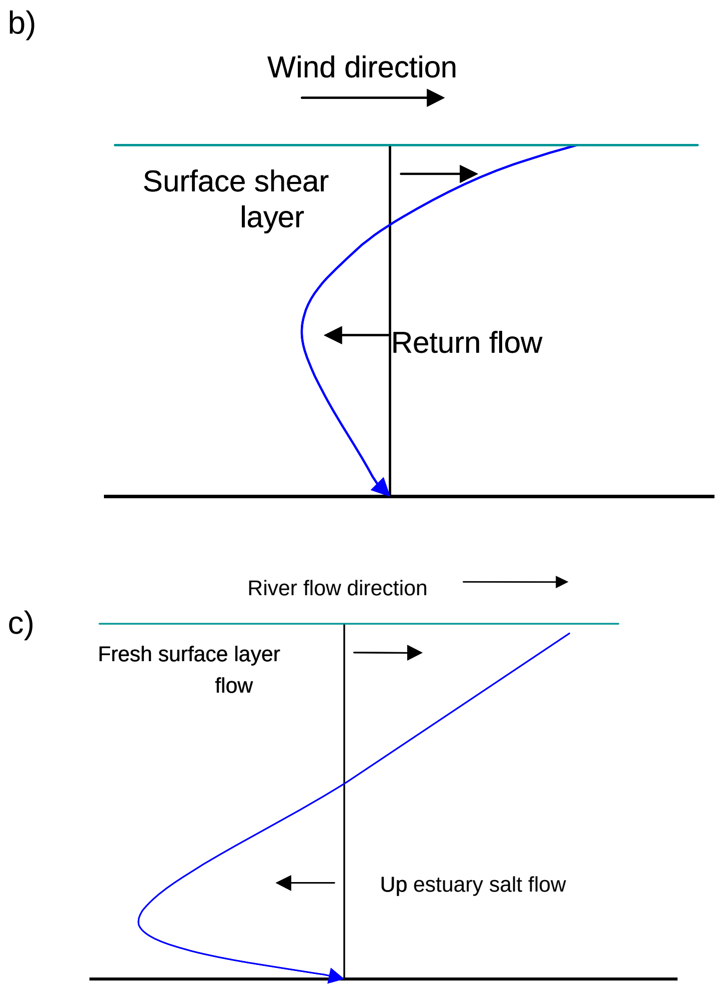


Figure 1. Typical vertical profiles for currents generated by different mechanisms. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main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

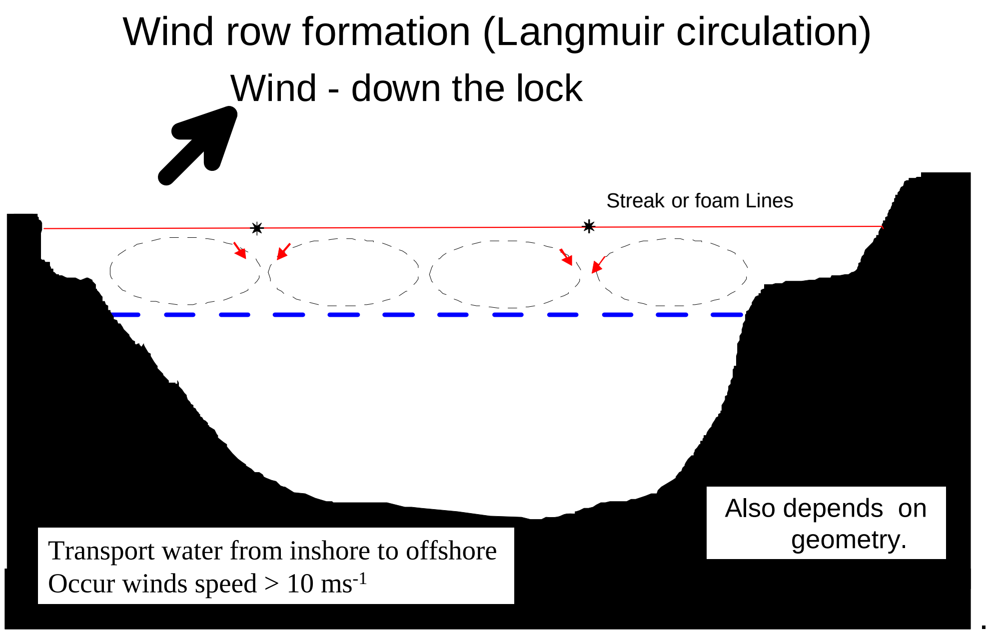


Figure 2: Schematic of wind driven 'wind row' currents. View is down the loch.The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Norovirus Testing Summary
Islay: Loch Gruinart Craigens

Oyster samples taken from the oyster farm at Loch Gruinart were submitted for Norovirus analysis quarterly between November 2007 and August 2008.

Results are tabulated below. No samples tested positive for norovirus during this period.

Ref No.	Date rec'd	NGR	GI	GII
07/761	23/11/07	NR 30246 71155	Not detected	Not detected
08/28	21/02/08	NR 30244 71160	Not detected	Not detected
08/130	22/05/08	NR 30240 71157	Not detected	Not detected
08/163	19/08/08	NR 30243 71158	Not detected	Not detected