Scottish Sanitary Survey Report

Sanitary Survey Report
Loch na Keal and Loch na Keal West
AB-284 and AB-286
June 2014

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Partner Organisations

The hydrographic assessment and the shoreline survey and its associated report were undertaken by SRSL, Oban.

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I. Executive Summary

Under (EC) Regulation 854/2004, which sets forth specific rules for the organisation of official controls on products of animal origin intended for human consumption, sanitary surveys of production areas and their associated hydrological catchments and coastal waters are required in order to establish the appropriate representative monitoring points (RMPs) for the monitoring programme.

The purpose of the sanitary survey is to demonstrate compliance with the requirements stated in Annex II (Chapter II Paragraph 6) of Regulation (EC) 854/2004. The sanitary survey results in recommendations on the location of RMPs, the frequency of sampling for microbiological monitoring, and the boundaries of the production areas deemed to be represented by the RMPs. A sanitary survey was undertaken on the classified Pacific oyster fisheries at Loch na Keal and Loch na Keal West on the basis recommended in the European Union Reference Laboratory publication: "Microbiological Monitoring of Bivalve Mollusc Harvesting Area Guide to Good Practice: Technical Application" (http://www.crlcefas.org/gpg.asp). These areas was selected for survey at this time based on a risk-based ranking amongst those Scottish production areas that had yet to receive a survey.

Loch na Keal is a west facing sea loch on the west coast of the Isle of Mull and is part of the Argyll and Bute council area.

Pacific oyster production at the Loch na Keal production area consists of baskets hung at 2-4 metres depth from longlines set a short distance from shore. At Loch na Keal West, Pacific oysters are grown on trestles on the intertidal area at the head of Port a Chlaidh, an inlet between the mainland of Mull and the islet of Eilean Casach. The representative monitoring point for Loch na Keal West is located approximately 200 m south of the currently active fishery.

The prinicipal sources of contamination to both production areas are:

- Diffuse agricultural-source faecal pollution, mainly from sheep
- A very small number of septic tank discharges to watercourses

There are a greater number of occupied properties a short distance north of the Loch na Keal West production area, a number of which do not have consents for discharge of sewage but are presumed to be on private septic systems of some form. There is also improved pasture adjacent to the northeast shoreline of the production area. At Loch na Keal, there is a large area of improved pasture used for grazing and at least one occupied property approximately 600 m inland from shore to the north of the oyster farm.

Two watercourses discharge to the Loch na Keal West production area and three to the Loch na Keal production area. Statistically significant associations were found between

historical *E. coli* monitoring results and rainfall in both the 2- and 7-day periods prior to sampling, suggesting this is a significant pathway for contamination to the fishery. Seasonal variation was seen in *E. coli* results at both production areas, with higher results generally in summer and autumn than in spring.

Although no statistically significant difference was found in monitoring results between the two production areas, the Loch na Keal West oyster farms potentially receive greater input from both human and agricultural sources of faecal contamination located nearby. Monitoring at this site has been undertaken at a trestle that no longer forms part of the active fishery and lies further from the identified potential sources of faecal contamination. Therefore, combining the two production areas is not supported by the evidence presented here.

It is recommended that the RMP for the Loch na Keal production area be shifted slightly to the northeast end of the longline to ensure that it reflects contaminating sources arising from watercourses discharging nearer to this end of the fishery. It is recommended that the RMP for the Loch na Keal West production area be restricted to the western half of Port a Chlaidh and that the RMP be moved to the southeast corner of the set of trestles on the west side of Port a Chlaidh to reflect potential contamination reaching the fishery via watercourses along the eastern shoreline.

Further details regarding the recommendations can be found in the sampling plan on the next page and in Section 18 of this report.

II. Sampling Plan

Production Area	Loch na Keal	Loch na Keal West
Site Name	Eilean Liath	Eilean Casach and unnamed site
SIN	AB-284-080-13	AB-286-082-13
Species	Pacific oyster	Pacific oyster
Type of Fishery	Longline aquaculture	Trestle aquaculture
NGR of RMP	NM 4749 3931	NM 4578 3910
East	147490	145783
North	739311	739102
Tolerance (m)	40	20
Depth (m)	4	Not applicable
Method of Sampling	Hand	Hand
Frequency of Sampling	Monthly	Monthly
Local Authority	Argyll & Bute Council	Argyll & Bute Council
Authorised Sampler(s)	Fraser Anderson William MacQuarrie Ewan McDougall Allison Hardie	Fraser Anderson William MacQuarrie Ewan McDougall Allison Hardie
Local Authority Liaison Officer	Fraser Anderson	Fraser Anderson
Production Area Boundaries	The area bounded by lines drawn between NM 4700 3908 and NM 4700 3890 and between NM 4800 3890 to NM 4800 3943	The area bounded by lines drawn from NM 4586 3924 to NM 4600 3880 to NM 4580 3880 to NM 4577 3894 and from NM 4570 3921 to NM 4569 3911, extending to MHWS

III. Report

1. General Description

Loch na Keal is a west facing sea loch on the west coast of the Isle of Mull and is part of the Argyll and Bute council area.

The loch has a total length of 10.7 km with an average depth of 26 m. The maximum depth recorded is 124 m.

The area surrounding Loch na Keal is sparsely populated with dwellings distributed around the shore of the loch. The majority of housing is located at the head of the loch around the three small settlements of Killiechronan, Gruline and Knock.

The sanitary survey was undertaken on the classified fisheries at Loch na Keal and Loch na Keal West on the basis recommended in the European Union Reference Laboratory publication: “Microbiological Monitoring of Bivalve Mollusc Harvesting Area Guide to Good Practice: Technical Application” (http://www.crlcefas.org/gpg.asp). This production area was selected for survey at this time based on a risk-based ranking of the area amongst those in Scotland that have yet to receive sanitary surveys.

Figure 1.1 Location of Loch na Keal and Loch na Keal West

2. Fishery

Loch na Keal and Loch na Keal West are both Pacific oyster (*Crassostrea gigas*) fisheries which have been classified for production since prior to 2001 and 2006 respectively. Details of the site are presented in Table 2.1

Table 2.1 Loch na Keal and Loch na Keal West shellfish farms

Production area	Site	SIN	Species
Loch na Keal	Eilean Liath	AB-284-080-13	Pacific oyster
Loch na Keal West	Eilean Casach	AB-286-082-13	Pacific oyster

The production area boundaries for Loch na Keal are given as: The area bounded by lines drawn between NM 4700 3908 and NM 4700 3890 and between NM 4800 3890 to NM 4800 3943. The RMP is located at NM 4742 3929.

The production area boundaries for Loch na Keal West are given as: The area bounded by lines drawn between NM 4616 3880 and NM 4580 3880 and between NM 4580 3880 and NM 4577 3894 and between NM 4569 3911 and NM 4570 3921. The RMP is given as NM 4584 3891.

At the time of shoreline survey, the Eilean Liath site consisted of baskets of Pacific oysters suspended at a depth of 2-4 m from a longline set approximately 360 m to the northeast of Eliean Liath. Only one longline was present at the time, but further longlines were planned. Although the exact location of these were not specified, it is presumed that additional lines would be set to the south of the existing line, which lies within 100 m of the adjacent shoreline to the north.

The Eilean Casach site consisted of approximately 250 trestles of used for growing Pacific oysters on the intertidal shoreline between Port a Chlaid and the Sound of Ulva.

Another area of trestles was reported east of the Eilean Casach site. There were five trestles, three of which had poches with oysters in. This site has been damaged by winter storms with some loss of stock.

The fishery area recorded during the shoreline survey is presented in Figure 2.1 below.

Figure 2.1 Loch na Keal and Loch na Keal West Fishery

3. Human Population

Information was obtained from the General Register Office for Scotland on the population within the vicinity of Loch na Keal production areas at the time of the last census, which was in 2011. The census output areas surrounding Loch na Keal are shown mapped by population density in Figure 3.1. The population density is very low (< 2 people per km^2) in all of the output areas surrounding the loch.

Table 3.1. Census output areas and populations – Loch na Keal

Census Output Area	Population
S00069143	119
S00069144	134
S00069230	129

A road (B8073) runs around the coastline of the loch, mostly within a few hundred metres of the shoreline. Residential dwellings are sparsely distributed along this road.. The small settlements of Killiechronan, Gruline and Knock are located at the eastern end of the loch. At Killiechronan there is a pony trekking centre, a campsite and an estate offering eight self-catering holiday cottages sleeping 2, 4 or 6 people. At Gruline. There are a further three self-catering cottages and a second estate at Knock has a letting house (sleeps 24) and three self-catering cottages including the cottage on the southern shoreline of the loch.

There is further development apparent in satellite imagery just to the west of Geedandhu, where a new spur diverts westward from the track. Information was sought via the Argyll & Bute Council Planning Portal (http://www.argyll-bute.gov.uk/planning-and-environment/find-and-comment-planning-applications#find) on planning applications submitted for the Ulva Ferry area since 1 January 2000. Only applications relating to change of use to residential or construction of new residential properties were considered further. Eight of these were located within 2 km of the shellfish farms and are displayed on the map in Figure 3.1. Three applications related to the development of new dwellings (one of which is also a B&B) along the Allt na Criche, northeast of the damaged trestles at Port a Chlaidh.

West of Loch na Keal, in the Sound of Ulva, an on-demand passenger ferry runs weekdays (also Sundays from 1st June – 31st August) from the Isle of Mull to the Isle Ulva (http://www.isleofulva.com/visitor-information/). There are a total of seven anchorages in the area, the closest of which is less than 500 m north west of the Loch na Keal West production area (Clyde Cruising Club, 2007; Hydrographic Office of the United Kingdom, 1993). Due to the number of anchorages in the area, leisure boat traffic is likely to be moderate. During the shoreline survey 13 moorings (6 of

which were occupied) were observed adjacent to the Ulva ferry slipway and a further two moorings were observed within the boundaries of the Loch na Keal West production area.

The presence of visitor accommodation and moorings suggests that there is likely to be significant seasonal variation in human population around the loch.

Overall, the local population is low and sparsely distributed however in relation to the fisheries, the oyster trestles at Loch na Keal West are likely to be more impacted by human-related sources due to the presence nearby of both homes and anchorages.

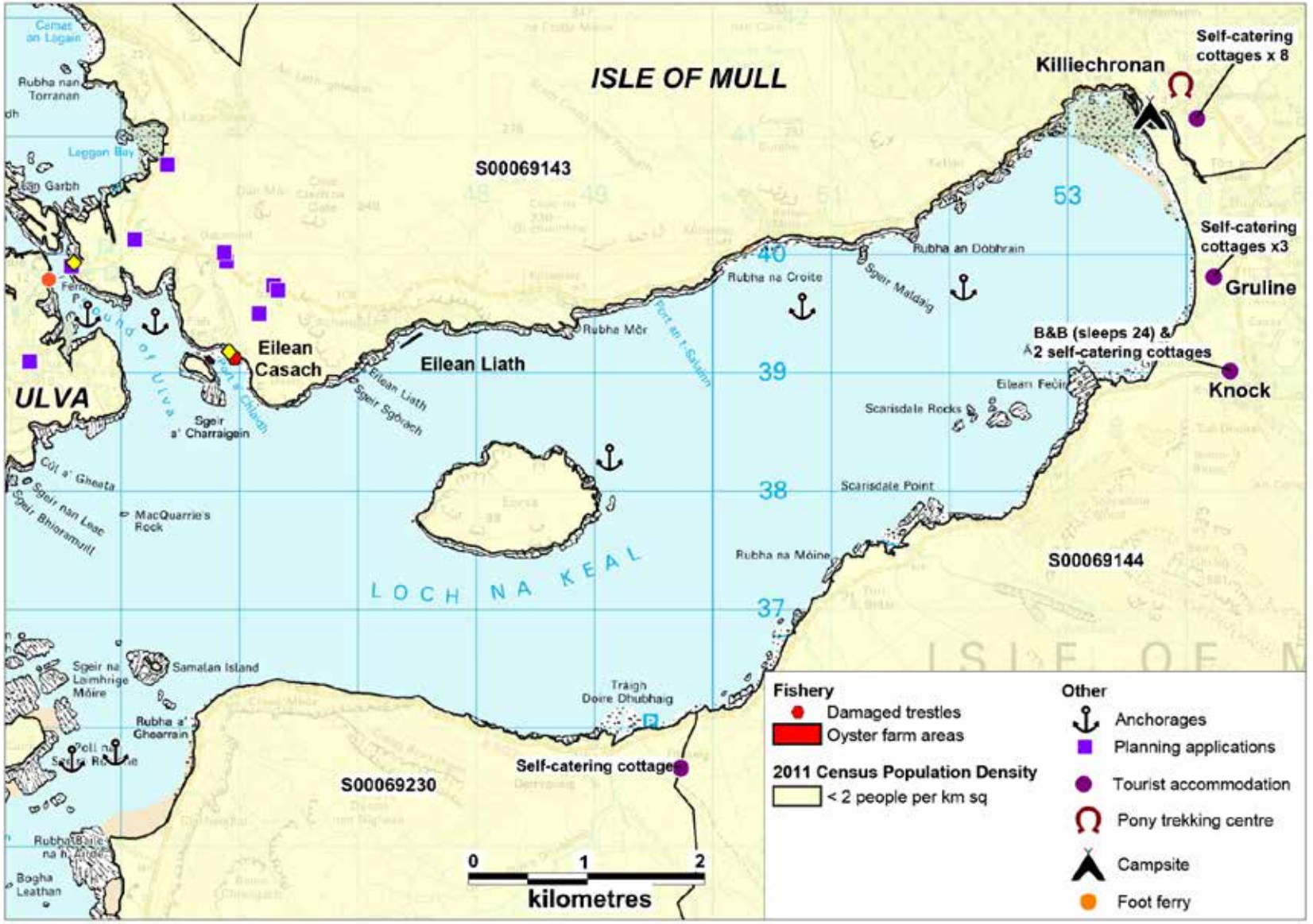


Figure 3.1 Population map for the area in the vicinity of Loch na Keal

4. Sewage Discharges

Information on sewage discharges within an area 10 km around the point NM 4700 3800 was sought from Scottish Water and the Scottish Environment Protection Agency (SEPA). Data requested included the name, location, type, size (in either flow or population equivalent), level of treatment, sanitary or bacteriological data, spill frequency, discharge destination (to land, to waterbody or to sea), any available dispersion or dilution modelling studies, and whether improvements were in work or planned.

4.1 Community Discharges

SEPA reported no community discharges within the requested area with Scottish Water confirming they have no assets within the requested area.

4.2 Private Discharge Consents

SEPA provided information regarding consented discharges within the request area identified. This assessment has excluded discharges relating to abstraction or engineering works, as they should not contribute any faecal input to the area.

Information was provided on 47 consented sewage discharges within the request area. Of these, only the 37 that are located within 2 km of the Loch na Keal shoreline are considered here. The private consented discharges beyond this distance are considered unlikely to significantly impact on water quality at the shellfisheries. All consented discharges assessed in this report are given in Appendix 6 and are shown in Figure 4.1. Table 4.1 presents details for those consented discharges within 2 km of either shellfish farm. These are the discharges considered most likely to contribute to faecal bacterial contamination at the fisheries.

Table 4.1 Private Discharges Adjacent to Production Area

Licence Number	National Grid Reference	Discharge Type	Discharging to	PE
CAR/R/1040278	NM 45824 40111	Sewage (Private) Primary	Soakaway	6
CAR/R/1041565	NM 46060 39860	Sewage (Private) Primary	Soakaway	6
CAR/R/1037758	NM 46110 39940	Sewage (Private) Primary	Soakaway	5
CAR/R/1096123	NM 46278 39649	Sewage (Private) Secondary	Allt na Criche	10
CAR/R/1080612	NM 46284 39781	Sewage (Private) Secondary	Allt na Criche	6

PE = Population Equivalent

Registration is required for all new properties and upon sale of existing properties. Information provided by SEPA is considered to be correct at the time of writing, however there may be additional discharges that are not yet registered with SEPA.

Two consented package sewage treatment works discharge to the watercourse Allt na Criche which flows into Port a Chlaidh, where the Eilean Casach site is located. Three discharges to land are located less than one kilometre uphill from the Loch na Keal West production area.

Shoreline Survey Discharge Observations

Observations made during the shoreline survey of sewage discharges and sewage-related infrastructure is listed in Table 4.3. The shoreline survey covered the shoreline from Ulva Ferry east to Port a' Chlaidh, and the shoreline adjacent to Loch na Keal production area at Creag Sginner.

Table 4.2 Discharge-associated observations made during the shoreline survey

No.	Date	Location (NGR)	Associated Photograph (Appendix)	Description
1	28/01/2014	NM 44579 39922	Figs. 10 & 11	10 cm metal pipe running from toilet block to loch. End of discharge pipe under water at time of survey therefore any discharge present undetectable. One male, one female toilet.
2	28/01/2014	NM 44574 39901	Fig. 12	10 cm metal pipe running from toilet block to loch. Discharge pipe ends in submerged chamber therefore any discharge present not detectable.[1]

[1]The harvester identified this as a redundant intake pipe.

Observations 1and 2 both related to the public toilet block at Ulva Ferry.

A seawater sample taken from between the two pipes, and approximately 10 m away from either, returned a result of 0 *E. coli* cfu/100ml. This suggests that either the pipes were not discharging at the time or that any discharge had no impact at the sampled point.

Summary

The area around Loch na Keal is sparsely inhabited and this is reflected in the small number of consented sewage discharges. The majority of consented discharges are recorded as discharging to soakaway and are located around the head of the Loch na Keal, which lies approximately 6.5 km east of the Eilean Liath shellfish farm.

Several consents are located uphill from Loch na Keal west production area with two of these discharging to a watercourse which flows directly into the production area. These two discharges have a combined PE of 16. However, it was not clear whether these two consents represent discharges from the four properties located in that vicinity.

No information was received on discharge consents relating to properties circled in magenta in Figure 4.1. These include private homes, a school, a fish farm base, and public toilets. The fish farm base is located at the head of Port a Chlaid, and though no outfall pipe was observed during the shoreline survey, any toilet facilities associated with the shore base would require some form of private septic waste disposal.

The shoreline survey recorded a public toilet block at Ulva ferry discharging to the sound between Ulva and Mull. No corresponding consent was provided for this observation, however a planning application was found for the replacement of the toilet block in 2003.

It is likely that any impact this source has on the fishery would be highly seasonal, with greater use expected during summer.

Many of the private sewage consents are recorded as discharging to land near to watercourses. If any of these have been diverted to watercourses, they may cause additional impact on the fishery.

The Loch na Keal West production area is likely to be impacted by discharges of sewage to Allt na Criche, which flows into Port a Chlaidh approximately 135 m southeast of the damaged trestles and just over 300 metres from the main area of production at Eilean Casach. It would also be affected by any diffuse contamination arising from poorly maintained or sited septic tanks and soakaway systems on properties uphill from the farm. Although there were no reported discharges to the Loch na Keal production area, there is a private house adjacent to the road and a watercourse (Allt Mor) that runs into the east side of the production area. Any discharges from this property to the watercourse may contribute faecal contamination to the east end of the production area.

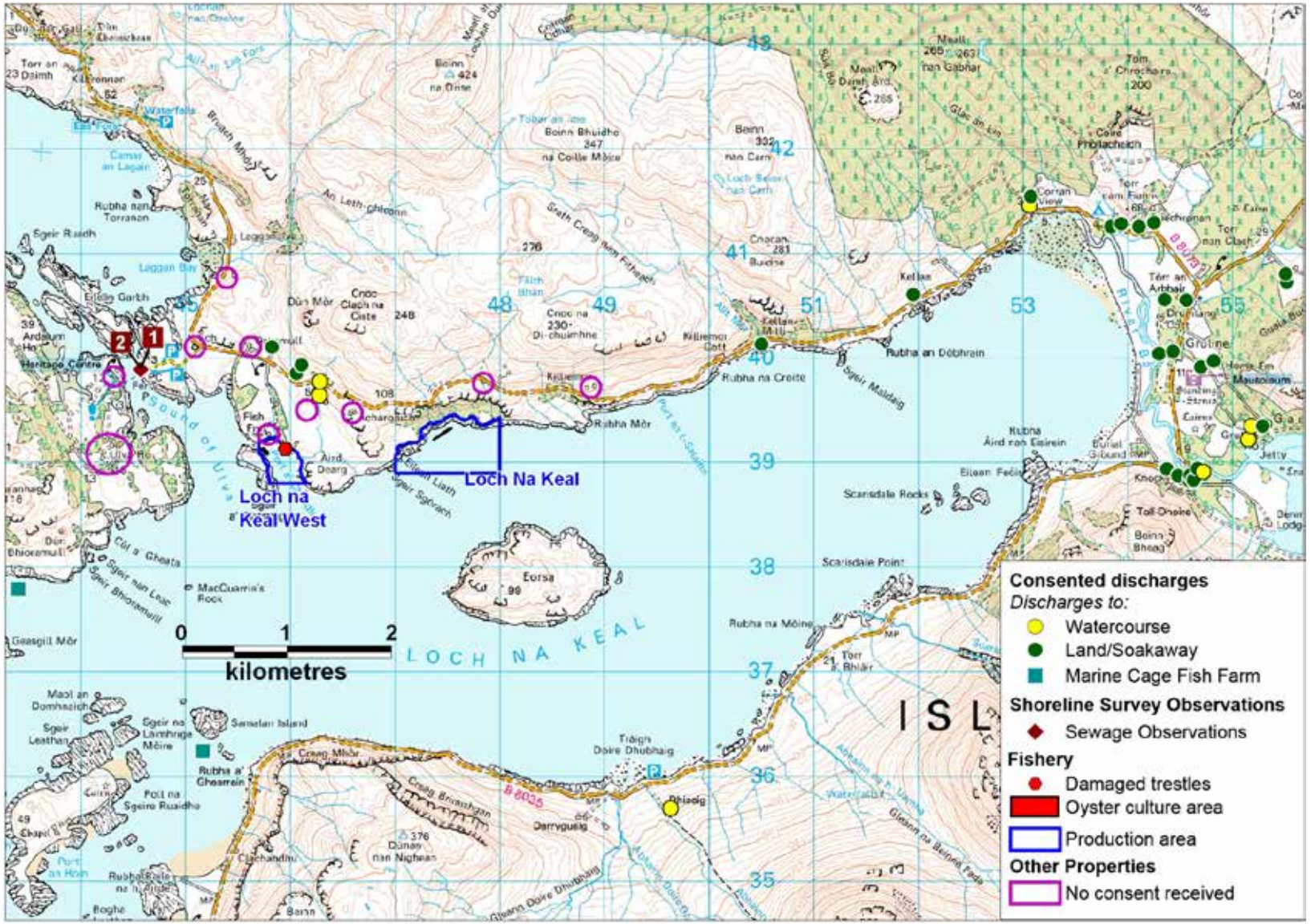


Figure 4.1 Map of discharges around Loch na Keal

5. Agriculture

Information on the spatial distribution of animals on land adjacent to or near the fishery can provide an indication of the potential amount of organic pollution from livestock entering the shellfish farm areas. Agricultural census data to parish level was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for the Kilninian and Kilmore, Kilfinichen and Kilvickeon and Torosay parishes. Reported livestock populations for the parishes in 2012 are listed in Table 5.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reporting would have made it possible to discern individual farm data. Any entries which relate to less than five holdings, or where two or fewer holdings account for 85% or more of the information, are replaced with an asterisk.

Table 5.1 Livestock numbers in the Kilninian and Kilmore, Kilfinichen and Kilvickeon and Torosay agricultural parishes 2012

	Kilninian and Kilmore		Kilfinichen and Kilvickeon		Torosay	
	306 km^2		247 km^2		367 km^2	
	Holdings	Numbers	Holdings	Numbers	Holdings	Numbers
Pigs	*	*	*	*	*	*
Poultry	16	442	24	396	8	215
Cattle	24	1366	31	1134	12	862
Sheep	36	16184	43	14571	14	12107
Other horses and ponies	10	48	9	26	7	19

* data withheld

The livestock census numbers for Kilninian and Kilmore, Kilfinichen and Kilvickeon and Torosay relate to very large parish areas covering all of the Isle of Mull as well as some smaller islands around it, including Ulva. It is not possible to determine the spatial distribution of the livestock on the shorelines adjacent to the loch or identify how many animals are likely to impact the catchment around the fisheries. Therefore, the figures are of little use in assessing the potential impact of livestock contamination to the fisheries; however they do give an idea of the total numbers of livestock over the broader area. Sheep are the most numerous livestock type kept whilst cattle were present in moderate numbers with poultry and other horses and ponies present in small numbers. Fewer than five holdings of pigs were reported for each parish.

A pony trekking club with approximately 13 ponies is located in Killinchronan, at the eastern end of the loch (Mull Pony Treking, 2014). It offers pony treks in and around the area and along the beach at the head of the loch.

One source of spatially relevant information on livestock population in the area was the shoreline survey (see Appendix 5) which only relates to the time of the site visit on the 28th January 2014. The shoreline survey was limited to the shoreline adjacent to the two production areas and the area around Ulva Ferry. Observations made during the survey are dependent upon the viewpoint of the observer some animals may have been

obscured by the terrain. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 5.1.

Few sheep were noted along the shorelines adjacent to the fisheries, with only eight sheep in total observed and no more than four observed in any location. SEPA identified a consented sheep dip on the southeastern shoreline, near the head of the loch. A second sheep dip to the north of the Loch na Keal West production area was identified on the Ordnance Survey map. However, it is not known whether this dip is still in use. The harvester noted that this sheep dip has not been used for several years.

Review of publicly available aerial images shows that areas of improved pasture are located at the head of the loch and along the northern shoreline of the loch including on the shoreline adjacent to the oyster trestles on the east side of Port a Chlaidh. (Bing Maps, accessed 25/04/2014 (imaging date Apr-May 2012, http://mvexel.dev.openstreetmap.org/bing/)). Significant numbers of livestock were clearly visible on pastures around the loch, with greatest numbers seen around the loch head and around Lagganulva, approximately 2 km north of Port a Chlaidh. A pig farm was also visible at Lagganulva. During consultation on the draft report, the harvester identified that pigs were only historically kept at this location and are no longer present. Livestock were visible on pasture approximately 600 m north of the long line oyster site at Eilean Liath. Areas identified from the aerial images as likely improved pasture are shown in Figure 5.1. Those on which livestock were visible are marked with a “+”.

Numbers of sheep are expected to be approximately double during the spring and summer months when lambs are present. Any contributions of faecal contamination from livestock grazing in the area would potentially affect those shellfish grown in shallower water closest to the shore. The largest concentration of livestock was seen at the head of the loch, however livestock present along the shore north of the fisheries and along watercourses draining into the production areas would be expected to have the greatest impact. Based on the distribution of animals and pasture seen in satellite images, impacts may be expected to be greatest at the northeast end of the Loch na Keal production area and to the north Port a Chlaidh in the Loch na Keal West production area.

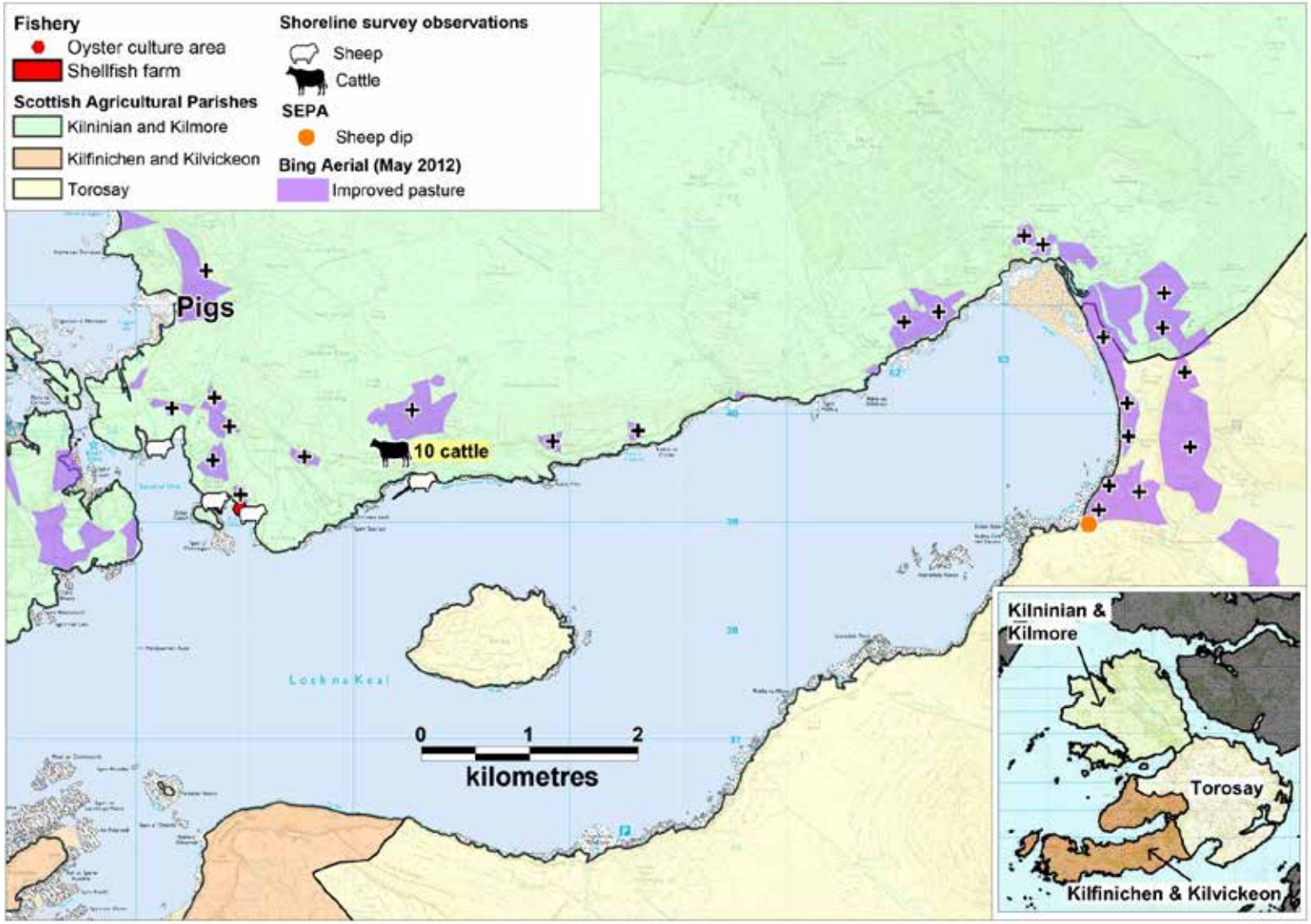


Figure 5.1 Livestock observations at Loch na Keal

6. Wildlife

Wildlife species present in and around the production area will contribute to background levels of faecal contamination at the fishery, and large concentrations of animals may constitute significant sources when they are present. Seals (pinnipeds), whales (cetaceans) and some seabirds may deposit faecal/cloacal wastes directly into the sea, whilst birds and mammals present on land will contribute a proportion of any faecal indicator loading carried in diffuse run-off or watercourses.

The species most likely to contribute to faecal indicator levels around the Pacific oyster fisheries at Loch na Keal and Loch na Keal West are considered below.

Pinnipeds

In a report by the Special Committee on Seals (SCOS, 2012) it was reported that between 2007 and 2011 approximately 100 harbour seals were observed in the Loch na Keal area, compared to only five grey seals seen in the area. Harbour seal populations on the west coast of Scotland are reported as being stable, whilst grey seal populations continue to increase (SCOS, 2012). It is expected the areas around Loch na Keal may be used from time to time by both seal species. During the shoreline survey no seals were observed.

Cetaceans

The waters around the Isle of Mull are reported as supporting various species of whales and dolphins. Due to the enclosed nature of the loch, it is not thought likely that the larger whale species will frequent Loch na Keal. However, harbour porpoises are reportedly seen off Gribun Cliffs, just outside Loch na Keal, south of Inch Kenneth island (Explore Mull, 2014). There is also a resident pod of bottlenose dolphins around Mull that is reported to use most of the inlets and waters around Mull. No cetaceans were observed during the shoreline survey.

Birds

Seabird 2000 census data (Mitchell, *et al*., 2004) was queried for the area within a 5 km radius of Loch na Keal and is summarised in Table 6.1. This census, undertaken between 1998 and 2002, covered twenty five species of seabird that breed regularly in Britain and Ireland.

Table 6.1 Seabird counts within 5 km of Loch na Keal

Common name	Species	Count*	Method
Herring gull	*Larus argentatus*	304	Occupied territory and nests
Great black-backed gull	*Larus marinus*	6	Occupied territory and nests
European shag	*Phalacrocorax aristotelis*	44	Occupied nests
Northern fulmar	*Fulmarus glacialis*	16	Occupied sites
Arctic tern	*Sterna paradisaea*	6	Occupied nests
Lesser black backed gull	*Larus fuscus*	2	Occupied territory

*Counts have been adjusted where the method used was occupied nests/territory to reflect the probable number of individual birds (i.e. counts of nests were doubled)

For the purposes of geographical representation, the start location data field was used as this was present in all records. Some of the counts refer to transects over larger areas than are represented by the single point shown in Figure 6.1. All Seabird 2000 records related to nesting locations associated with the islands of Geasgill Mor, Geasgill Beag, Inch Kenneth and Ulva. The greatest number of birds was recorded on Geasgill Mor, which hosted a large herring gull colony.

Anecdotal information also indicated that eagles, grebes and swans are found in the area. Wading birds are reported to be commonly found on the sandy/muddy intertidal areas in autumn and winter and diver species are common from winter to spring (http://www.wildfuture.co.uk/index.php/western-mull-places-to-go). Nesting shore birds, such as the common sandpiper and ringed plover, are reported to be common during the summer. No information was found regarding the local populations of any of these birds, however.

During the shoreline survey 10 gulls, two oystercatchers, one heron and two crows were recorded. The majority of these birds were located on the intertidal area around the Loch na Keal West oyster trestles.

Deer

Red deer are numerous on the Isle of Mull, with an estimated population of approximately 6,000 (Explore Mull, 2013). Two small herds of Fallow deer are reported to be found at Knock, approximately 7 km southeast of the fishery (Explore Mull, 2013). It is expected that deer will be present around the shorelines adjacent to the fisheries and will contribute to faecal contamination levels within watercourses entering the fishery area.

Otters

The Eurasian otter (*Lutra lutra*) is common on the Isle of Mull. There are no official reports on population numbers in the area, though there is anecdotal evidence of otters around the shores at Loch na Keal (Wildfuture website, 2014). One juvenile otter was observed during the survey, in the water near to the Loch na Keal fishery.

Overall

Wildlife are expected to contribute to background levels of contamination within the loch and at both fisheries. This will include contamination from seals, seabirds, deer and otters and other small mammals. Any impacts are likely to be greatest at the Loch na Keal West production area, where a larger number of birds may be present on the intertidal area and where watercourses flow into the loch nearer to the farmed shellfish.

Contamination arising from seabird nesting areas on islands to the southwest of the shellfish farms will be most likely to contribute faecal contamination to the loch in the summer months.

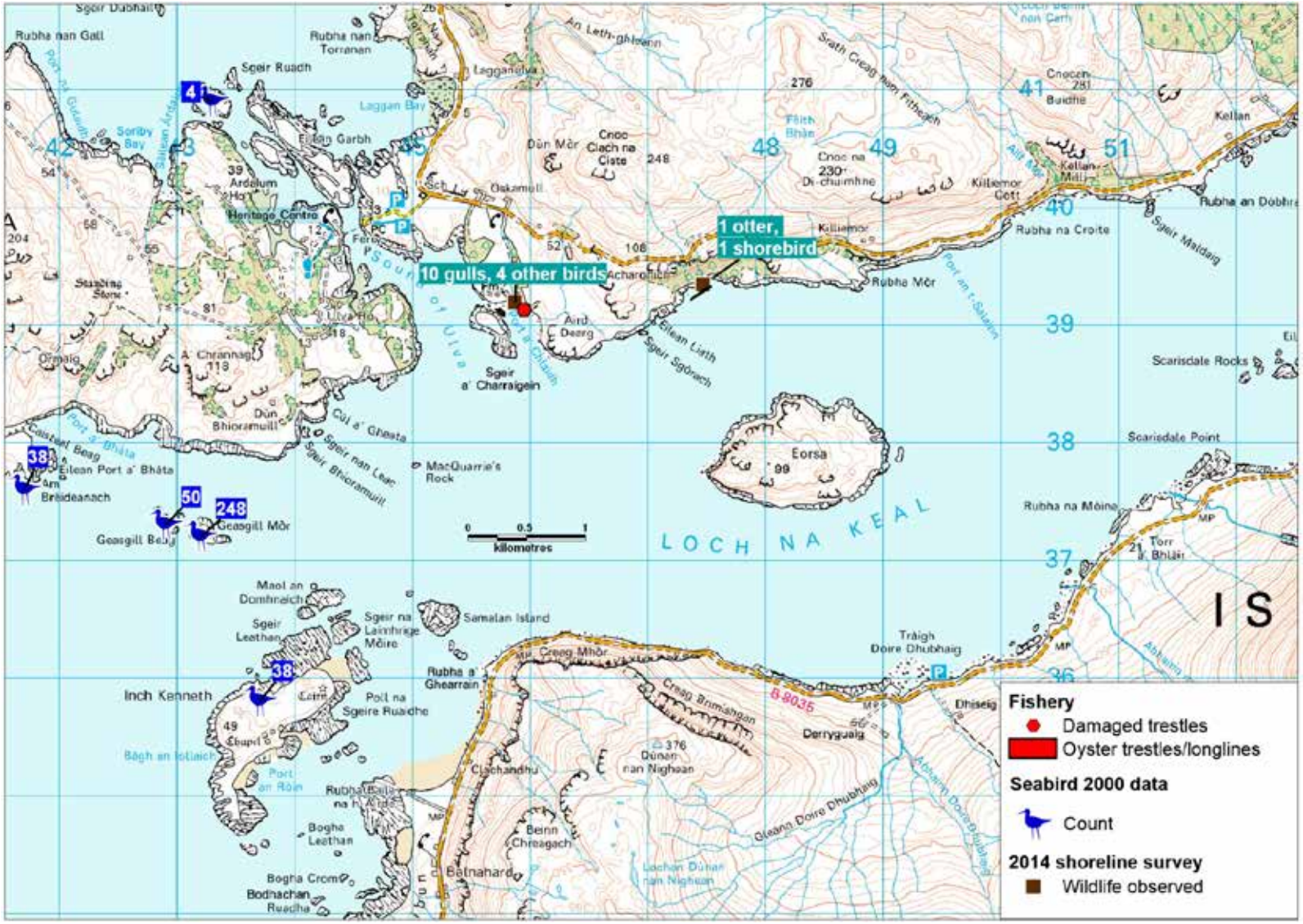


Figure 6.1 Map of wildlife around Loch na Keal

7. Land Cover

The Land Cover Map 2007 data for the area is shown in Figure 7.1 below:

The predominant land cover types adjacent to the Loch na Keal production areas are improved grassland, rough grassland, dwarf shrub heath and bog. There are also scattered small areas of coniferous woodland, broadleaved woodland and acid grassland. There is improved grassland on the shoreline directly adjacent to the Eilean Casach oyster farm and improved grassland within 1 km inland of the Eilean Liath oyster farm. There are no built up or urban areas represented.

Faecal indicator organism export coefficients for faecal coliform bacteria have been found to be approximately $8.3x10^8$ cfu/km^2/hr for areas of improved grassland and approximately $2.5x10^8$ cfu/km^2/hr for rough grazing (Kay, *et al*., 2008). The contributions from all land cover types would be expected to increase significantly after rainfall events, however this effect would be particularly marked from improved grassland areas (roughly 1000-fold) (Kay, *et al*., 2008).

The highest potential contribution of contaminated run-off to the Eilean Casach oyster farm is from the areas of improved grassland located along the north end of Port a Chlaidh. Any impact is likely to be greatest at the eastern set of trestles, where the improved grassland is adjacent to the shoreline.

At Eilean Liath, there is improved grassland area to the north of the oyster farm, and set well away from the shoreline. Therefore any potential contribution of contaminated run-off will be less direct than at Eilean Casach. This contribution would be expected to increase after rainfall events.

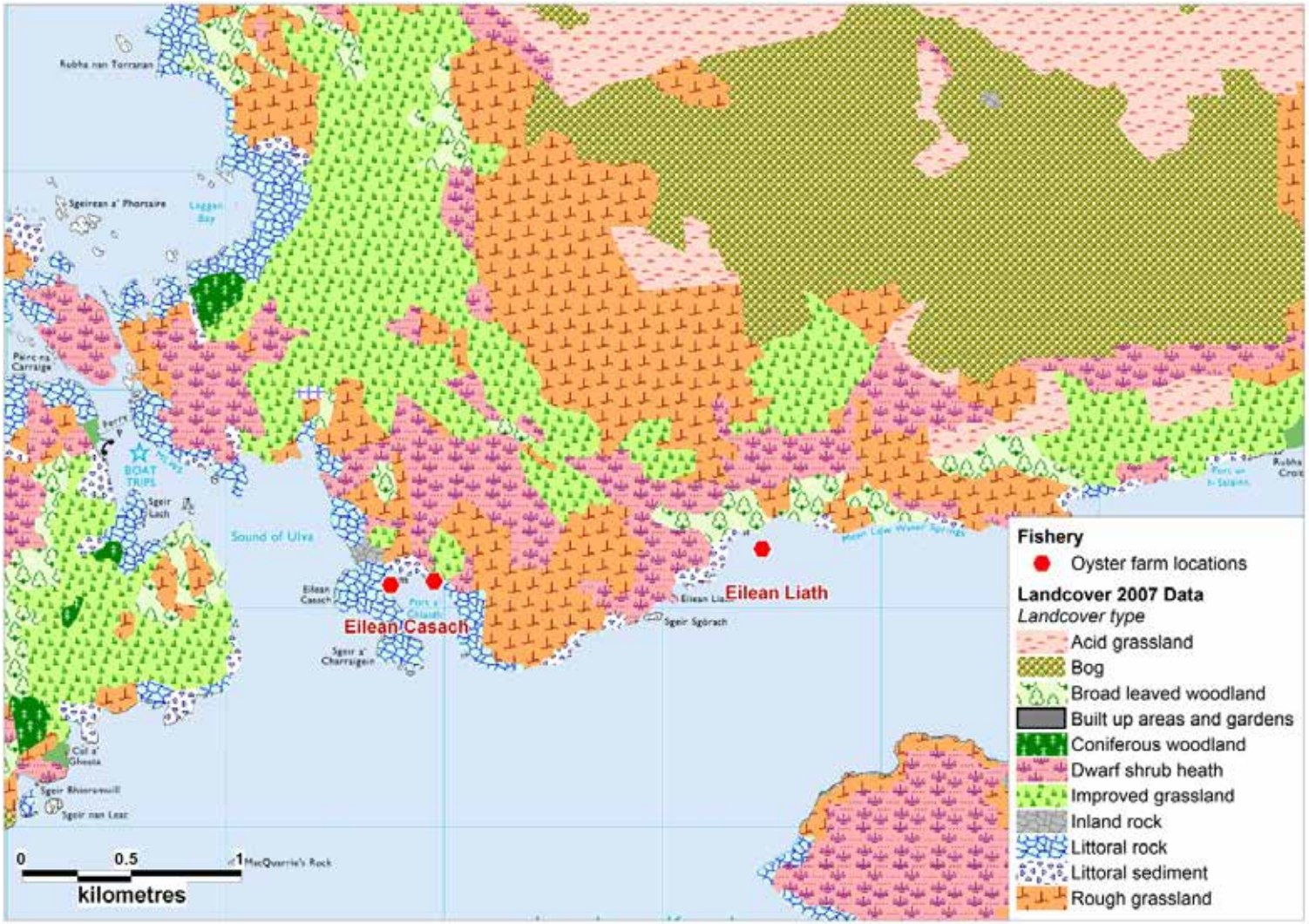


Figure 7.1 LCM2007 land cover data for the area around Loch na Keal

8. Watercourses

There are no gauging stations on the watercourses entering Loch na Keal.

During the shoreline survey, significant watercourses along the survey route were recorded and size, flow and *E. coli* concentrations were measured from spot samples. Weather conditions were dry during the survey. Watercourses that were recorded are listed in Table 8.1. The locations and loadings of measured watercourses as well as noted areas of land drainage are shown in Figure 8.1.

Table 8.1 Watercourses entering Loch na Keal

No.	Eastings	Northings	Description	Width (m)	Depth (m)	Flow (m^3/d)	Loading (*E. coli* per day)
1	147940	739424	Allt Mor	1.20	0.15	10669	$< 1.1 \times 10^{9**}$
2	147577	739452	Unnamed watercourse	0.55	0.10	3151	2.2×10^{9}
3	147479	739426	Allt Gual a Chruaidh-ghoirtein	1	0.15	4212	5.9×10^{9}
4	147394	739378	Unnamed watercourse	0.28*	0.06*	861*	8.6×10^{7}
5	146071	739073	Allt na Criche	1.20	0.13	6834	2.1×10^{9}
6	145870	739203	Unnamed watercourse	1.10	0.13	4053	1.3×10^{10}
7	145445	739888	Unnamed watercourse	0.50	0.09	2574	8.2×10^{9}
8	145207	739678	Unnamed watercourse	0.25	0.20	294	$< 2.9 \times 10^{7}$

* Average taken from two measurements ** Where *E. coli* values were less than the limit of detection, that value was used to estimate the upper limit for the loading.

None of the recorded watercourses flow through the shellfish farm areas. Unnamed watercourse Number 6, which had the highest calculated loading, and Allt na Criche both enter the Loch na Keal West production area within 150 m of the oyster trestle areas. Three watercourses (Allt Gual a Chruaidh-ghoirtein and two unnamed watercourses) discharged within 200 m of the Eilean Liath site. All of these had moderate calculated loadings. In addition, an area of land drainage that was too shallow to measure or sample was identified approximately 100 m east of the area of damaged trestles on the east side of Port a' Chlaidh. Livestock were observed grazing in the catchments of the watercourses numbered 2 through 6.

Overall, freshwater inputs are expected to provide moderate levels of contamination to the oyster beds in Loch na Keal, with the highest impact expected from the watercourses that discharge closest to the shellfish farms. Of these, the highest loading was observed from watercourse Number 6 which discharges within 150 m of both oyster farms within the Loch na Keal West production area.

Three watercourses with moderate loadings discharge near the Loch na Keal oyster area and would potentially impact on the eastern end.

Figure 8.1 Map of watercourse loadings at Loch na Keal

9. Meteorological Data

The nearest weather station with the most complete rainfall data history is located at Mull: Gruline, situated approximately 7 km east of the fishery. Rainfall data was available for January 2008 – December 2013 at the time of writing this report. Data was missing for 2 % of this time period. The nearest wind station is situated at Tiree, approximately 46 km west of the fishery. Data for these stations was purchased from the Meteorological Office. Unless otherwise identified, the content of this section (e.g. graphs) is based on further analysis of this data undertaken by Cefas. This section aims to describe the local rain and wind patterns in the context of the bacterial quality of shellfish at Loch na Keal.

9.1 Rainfall

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

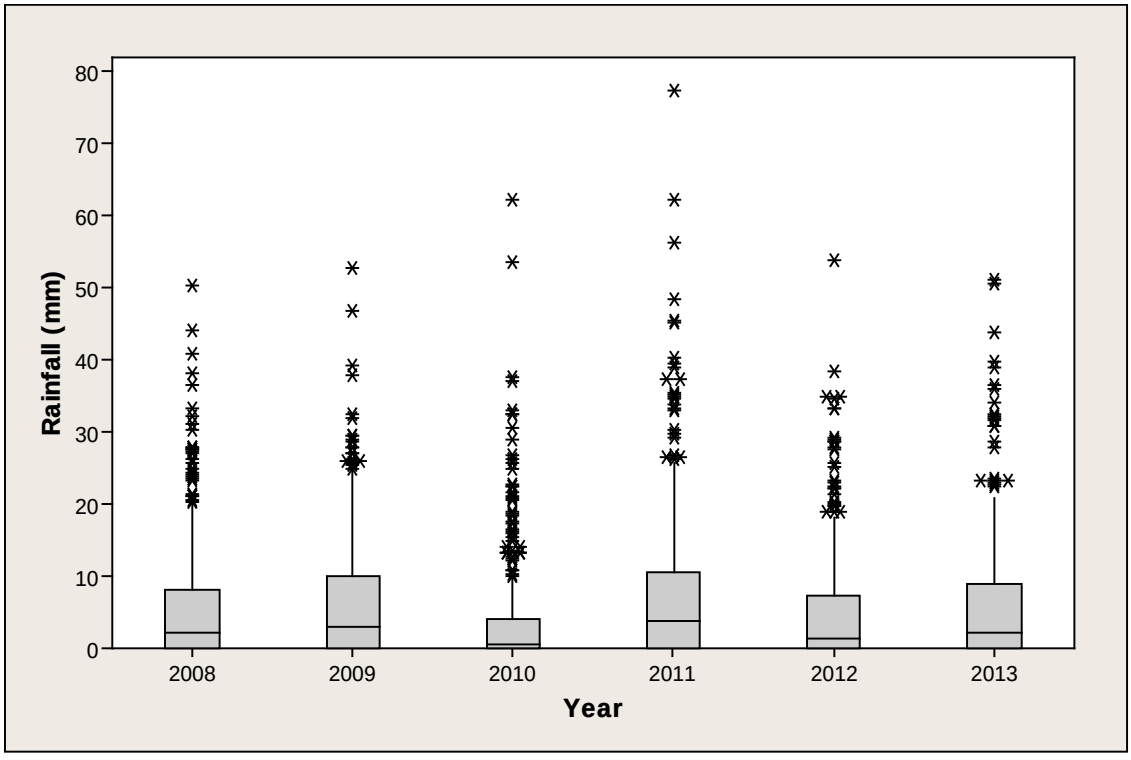


Figure 9.1 Box plot of daily rainfall values by year at Mull: Gruline (2008 – 2013)

Total rainfall values varied from year to year, with 2010 being the driest year (a total of 1427 mm). The wettest year was 2011 (a total of 2738 mm). High daily rainfall values of more than 30 mm/d occurred in all years and an extreme rainfall event of nearly 80 mm/d occurred in 2011.

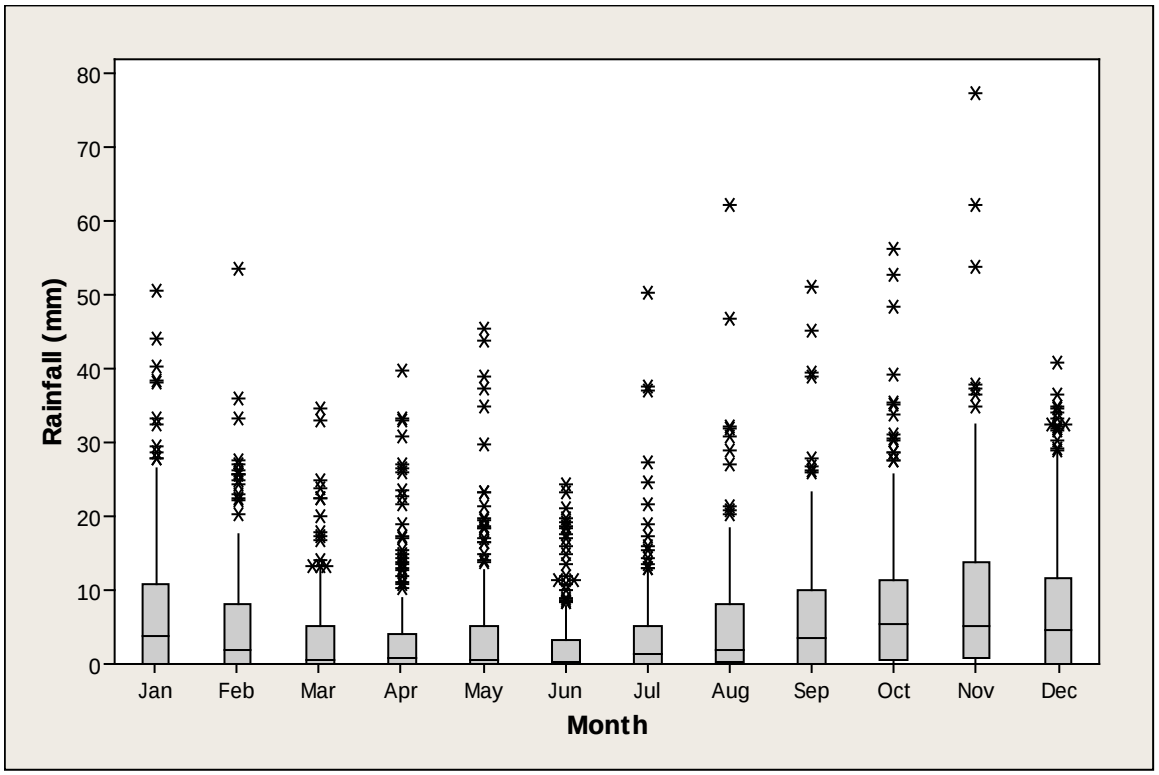


Figure 9.2 Box plot of daily rainfall values by month at Mull: Gruline (2008– 2013)

Rainfall was lowest in April and June and highest between October and January. Rainfall values exceeding 30 mm/d were recorded in all months apart from June. The highest recorded daily rainfall event occurred in November.

For the period considered here (2008 – 2013) 42 % of days received daily rainfall of less than 1 mm and 21 % of days received rainfall of over 10 mm.

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

9.2 Wind

Wind data was collected from Tiree and summarised in seasonal wind roses in Figure 9.3 and annually in Figure 9.4.

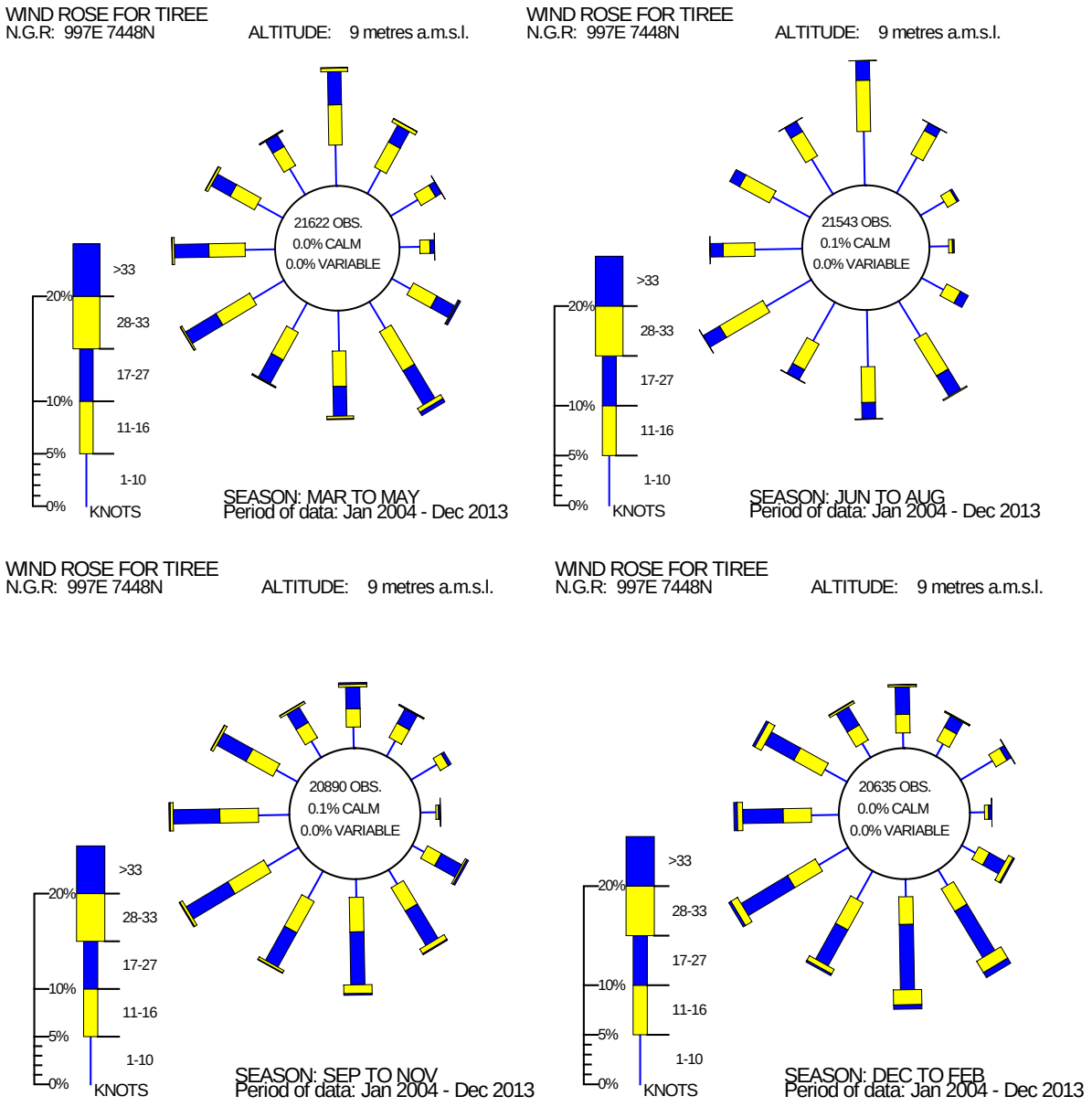


Figure 9.3 Seasonal wind roses for Tiree

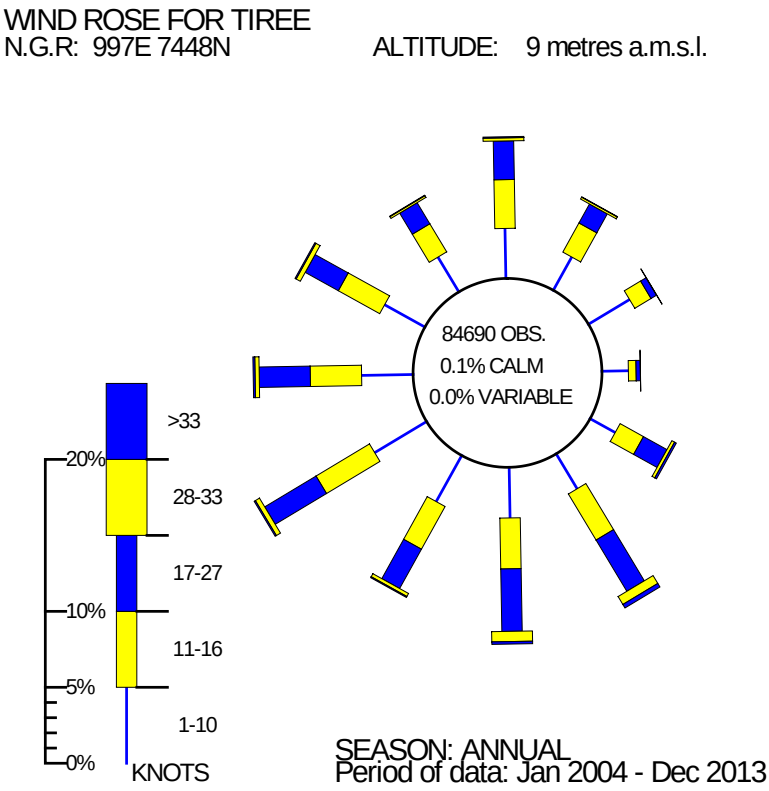


Figure reproduced under license from Meteorological Office. Crown Copyright 2014.

Figure 9.4 Annual wind rose for Tiree

Overall, predominant winds were from the SSE to WSW. Winds were least likely to blow from the east. Northerly winds occurred more frequently during spring and summer.

Wind is an important factor in the spread of contamination as it has the ability to drive surface water at about (3%) of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s. Therefore strong winds can significantly alter the pattern of surface currents. Strong winds also have the potential to affect tide height depending on wind direction and local hydrodynamics of the site. A strong wind combined with a spring tide may result in higher than usual tides, which will carry any accumulated faecal matter at and above the normal high water mark into the production area.

10. Classification Information

Loch na Keal and Loch na Keal West are classified for production of Pacific oysters (*C. gigas*). Loch na Keal has been classified for production since prior to 2001 and Loch na Keal West since 2006. The classification histories since April 2006 are listed in Tables 10.1 and 10.2

Table 10.1 Loch na Keal classification history

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2007				A	A	A	A	A	A	A	A	A
2008	A	A	A	A	A	A	A	A	A	A	A	A
2009	A	A	A	A	A	A	A	A	A	A	A	A
2010	A	A	A	A	A	A	A	A	A	A	A	A
2011	A	A	A	A	A	A	A	A	A	A	A	A
2012	A	A	A	A	A	A	A	A	A	A	A	A
2013	A	A	A	A	A	A	A	A	A	A	A	A
2014	A	A	A									

Table 10.2 Loch na Keal West classification history

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2007				A	A	A	A	A	A	A	A	A
2008	A	A	A	A	A	A	A	A	A	A	A	A
2009	A	A	A	A	A	A	A	A	A	A	A	A
2010	A	A	A	A	A	A	A	A	A	A	A	A
2011	A	A	A	A	A	A	A	A	A	A	A	A
2012	A	A	A	A	A	A	A	A	A	A	A	A
2013	A	A	A	A	A	A	A	A	A	A	A	A
2014	A	A	A									

Both production area have been consistently classified as A since April 2007.

11. Historical *E. coli* Data

11.1 Validation of historical data

Results for all samples assigned against Loch na Keal and Loch na Keal West production areas for the period 01/01/2008 to the 11/02/2014 were extracted from the FSAS database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. The data was extracted from the database on 11/02/2014. All *E. coli* results were reported as most probable number (MPN) per 100 g of shellfish flesh and intravalvular fluid.

All sample results reported as <20 were reassigned a value of 10 *E. coli* MPN/100 g for the purposes of statistical evaluation and graphical representation.

Loch na Keal

All 67 samples were reported as valid, were received within 48 hours since collection and were taken within the production area boundaries.

Loch na Keal West

All 69 samples were reported as valid. One sample was omitted as it appeared to be a duplicate result and no paper record was found. The remaining 68 samples were received within 48 hours since collection and were taken within the production area boundaries.

11.2 Summary of microbiological results

Table 11.1 Summary of historical sampling and results

Sampling Summary		
Production area	Loch na Keal	Loch na Keal West
Site	Eilean Liath	Eilean Casach
Species	Pacific oyster	
SIN	AB-284-080-13	AB-286-082-13
Location	Various	
Total no of samples	67	68
No. 2008	11	11
No. 2009	12	12
No. 2010	10	10
No. 2011	10	10
No. 2012	11	11
No. 2013	11	12
No. 2014	2	2
Results Summary		
Minimum	<20	<20
Maximum	490	2400
Median	<20	<20
Geometric mean	24	22
90 percentile	182	85
95 percentile	278	211
No. exceeding 230/100g	3 (5%)	2 (3%)
No. exceeding 1000/100g	0	1 (1%)
No. exceeding 4600/100g	0	0
No. exceeding 18000/100g	0	0

The majority of sample results from both production areas have been low at <20 *E. coli* MPN/100 g. The highest result (2400 *E. coli* MPN/100 g) was from a sample taken at Loch na Keal West. At both production areas, greater than 50% of sample results were below the limit of detection (<20 *E. coli* MPN/100 g).

11.3 Overall geographical pattern of results

The geographical locations of all sample results assigned to Loch na Keal and Loch na Keal West have been thematically mapped in Figure 11.1.

The majority of Loch na Keal samples have been taken within 50 m of the RMP at NM 4742 3929.

Sampling at Loch na Keal West has been predominantly within 100 m of the RMP at NM 4584 3891. Two samples were reported against grid references > 200 m from the RMP, however they were within the production area boundaries.

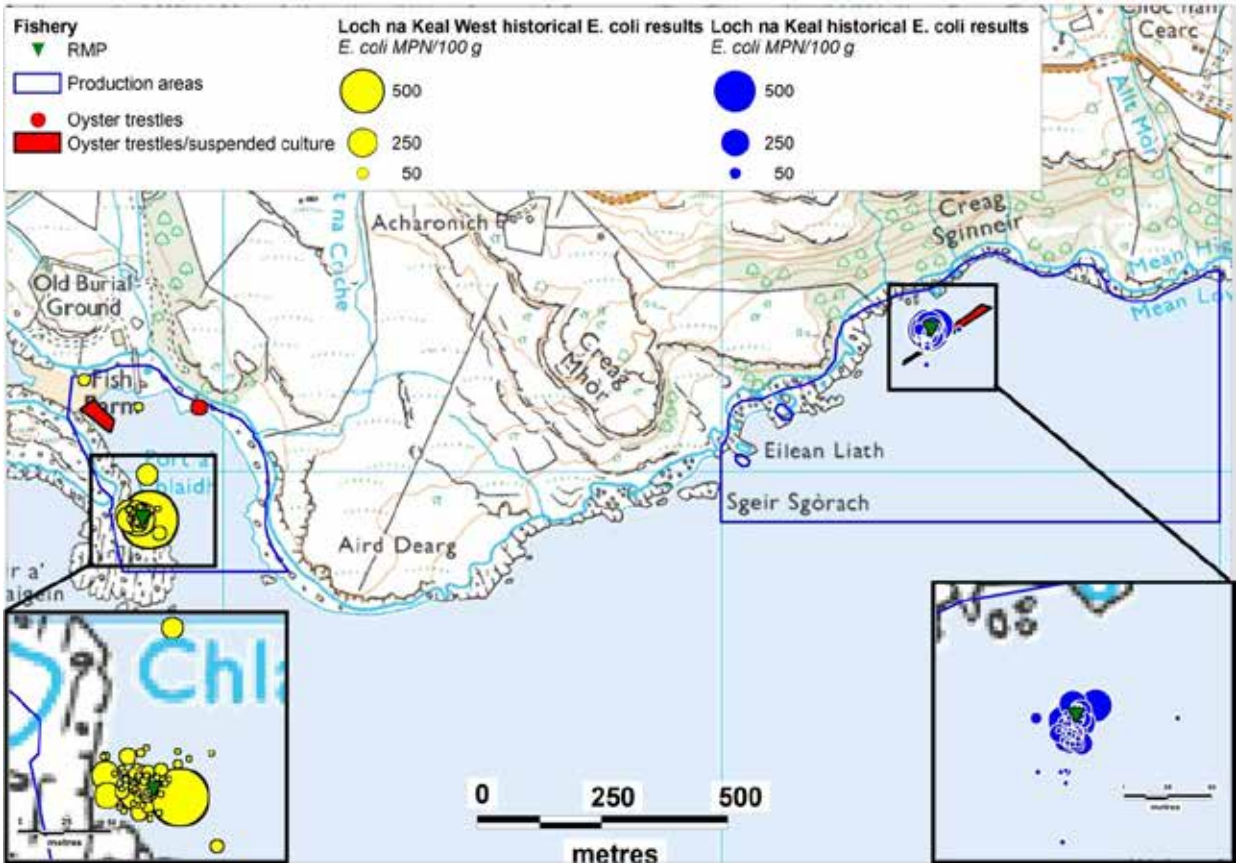


Figure 11.1 Map of reported sampling locations for Pacific oyster results taken at Loch na Keal and Loch na Keal West

A two sample t-test was conducted to determine whether there was a significant difference between sampling results taken at Loch na Keal and Loch na Keal West. No significant difference was found (Two sample t-test, T=0.56, df = 131, p = 0.577).

At Loch na Keal West, the highest recorded result was from a point to the southeast of the RMP. However, other elevated results were from locations west of the RMP and there is no clearly discernible pattern to these. The RMP and main area of sampling was located approximately 200 m south of the trestle area recorded during

the shoreline survey. No trestles were apparent at this location in satellite images from 2012, however the main area of trestles recorded during the survey were clearly visible (http://mvexel.dev.openstreetmap.org/bing/, Accessed 29/04/2014). The shoreline survey team recorded a monitoring point at location of the RMP.

At Loch na Keal, the highest results tended to be clustered relatively tightly around the RMP. Most samples were taken from locations nearly mid way along the longline and approximately 20 m north of the area recorded during the shoreline survey.

11.4 Overall temporal pattern of results

Scatterplots of *E. coli* results against date for Loch na Keal and Loch na Keal West are presented in Figures 11.2 and 11.3 respectively. The datasets are fitted with a lowess trend line. Lowess trendlines allow for locally weighted regression scatter plot smoothing. At each point in the dataset an estimated value is fitted to a subset of the data, using weighted least squares. The approach gives more weight to points near to the x-value where the estimate is being made and less weight to points further away. In terms of the monitoring data, this means that any point on the lowess line is influenced more by the data close to it (in time) and less by the data further away. A trend line helps to highlight any apparent underlying trends or cycles.

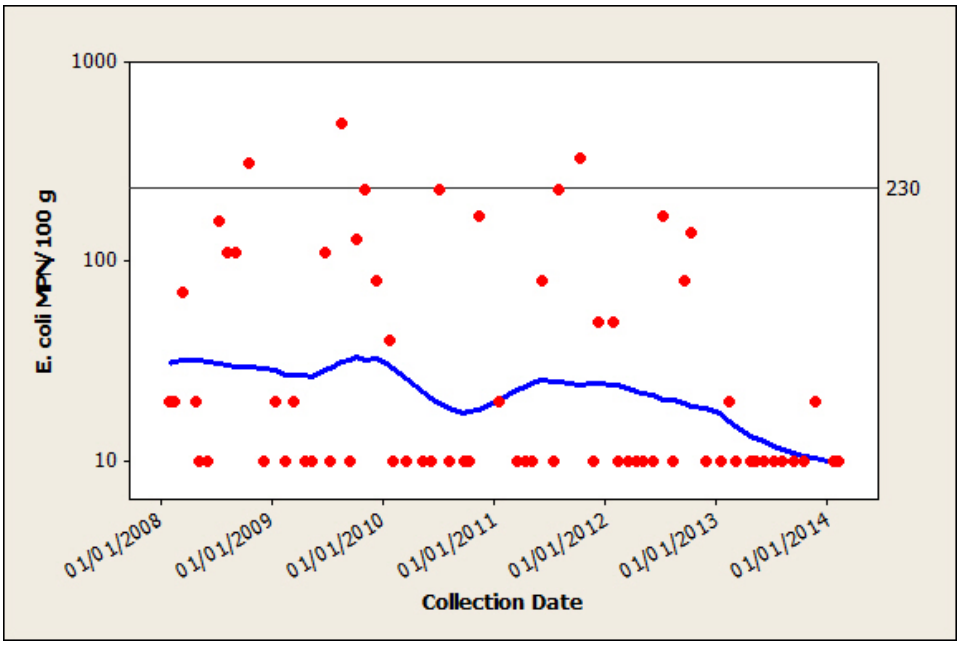


Figure 11.2 Scatterplot of *E. coli* results by collection date at Loch na Keal, fitted with a lowess line

E. coli monitoring results at Loch na Keal show an overall downward trend, with no results exceeding 100 *E. coli* MPN/100 g since late 2012.

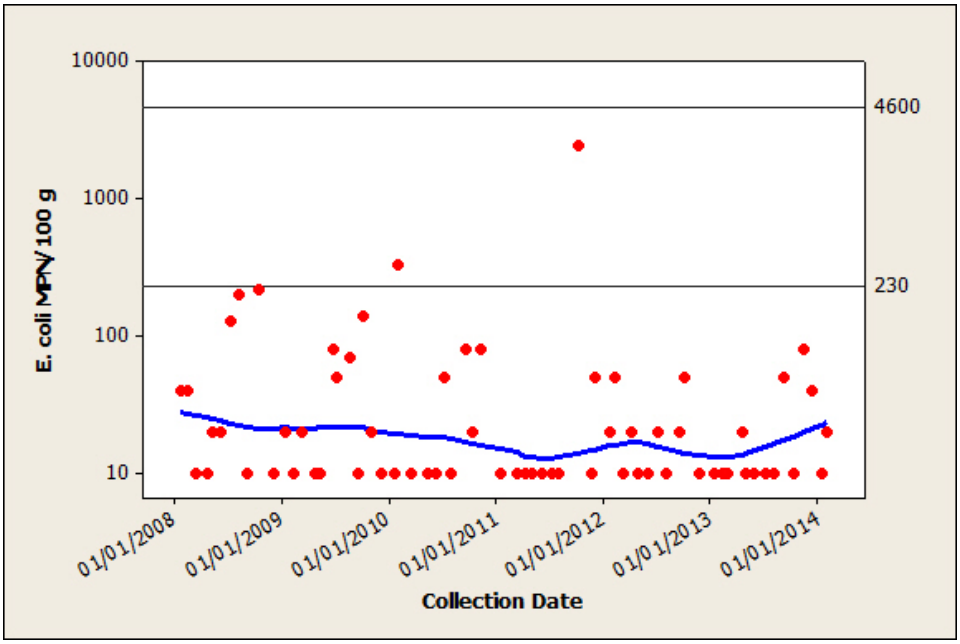


Figure 11.3 Scatterplot of *E. coli* results by collection date at Loch na Keal West, fitted with a lowess line

E. coli monitoring results remained level over the sampling period, with the majority of results <100 *E. coli* MPN/100 g. One result exceeding 1000 *E. coli* MPN/100 g occurred in 2011.

11.5 Seasonal pattern of results

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns in human distribution. All of these can affect levels of microbial contamination, causing seasonal patterns in results. Scatterplots of *E. coli* results by month, overlaid by a lowess line to highlight trends for Loch na Keal and Loch na Keal West are displayed in Figures 11.4 and 11.5. Jittering was applied to both figures at 0.02 (x-axis) and 0.001 (y-axis) respectively.

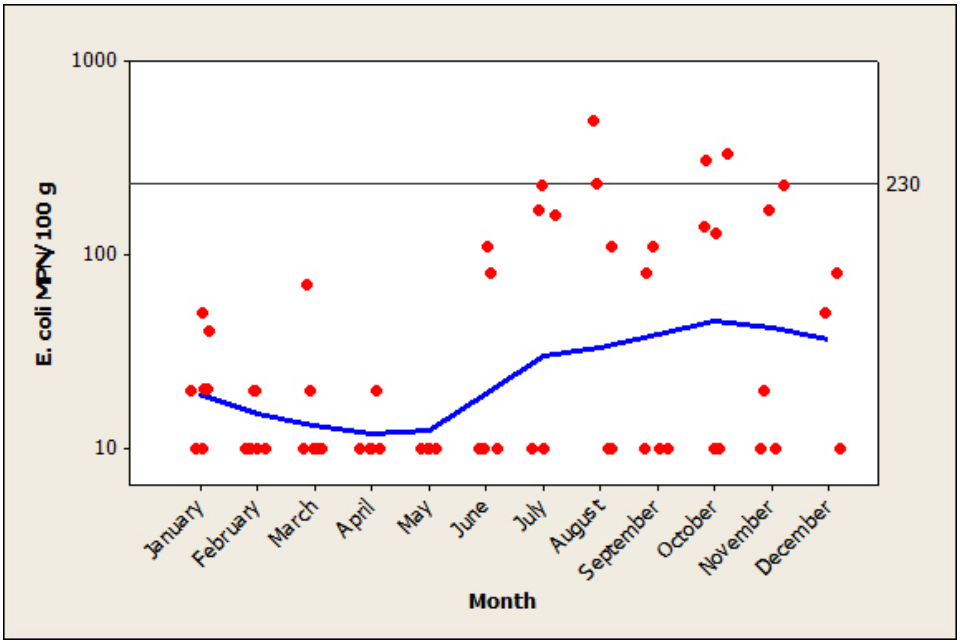


Figure 11.4 Scatterplot of *E. coli* results by month at Loch na Keal, fitted with a lowess line

E. coli monitoring results show marked seasonal change, with higher results occurring from June to November. The highest results (>230 *E. coli* MPN/100 g) occurred in August and October.

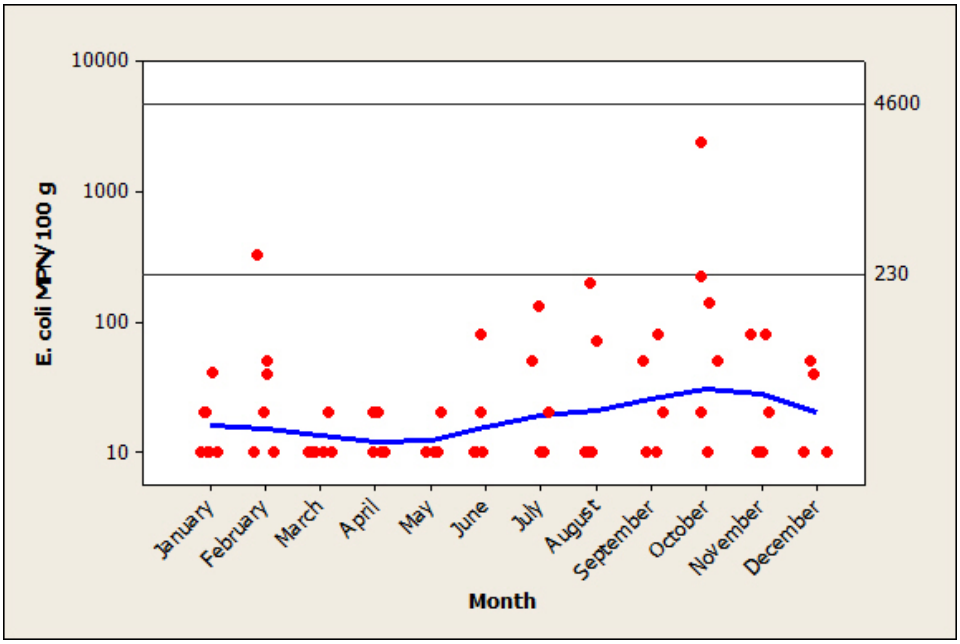


Figure 11.5 Scatterplot of *E. coli* results by month at Loch na Keal West, fitted with a lowess line

E. coli monitoring results show a much less pronounced seasonal increase at Loch na Keal West than at Loch na Keal. Results were lowest from March to May whilst the highest result occurred in October.

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

Boxplots of *E. coli* results by season for Loch na Keal and Loch na Keal West are presented in Figures 11.6 and 11.7 respectively.

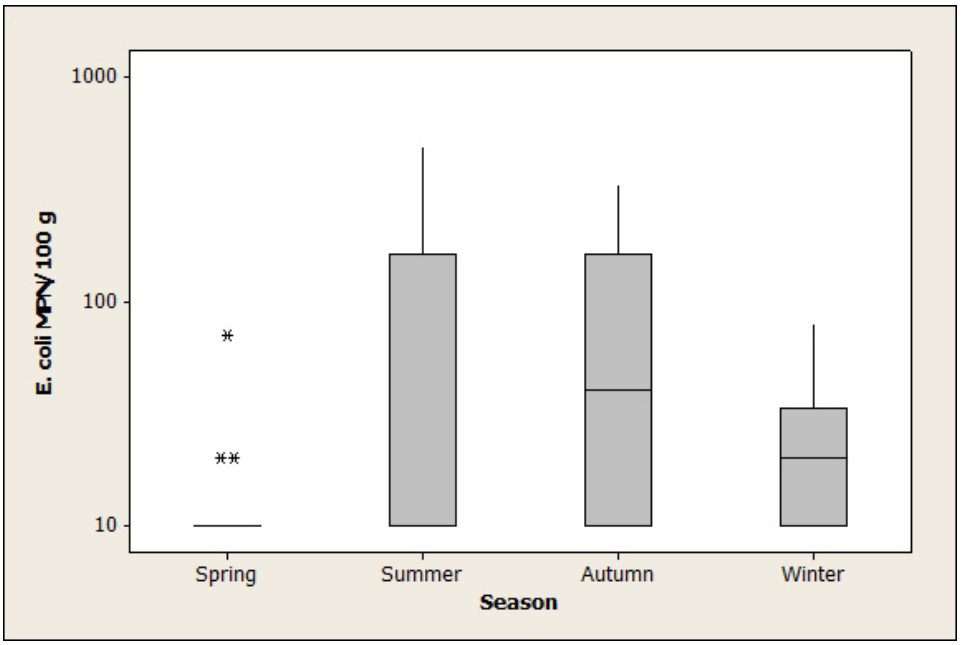


Figure 11.6 Boxplot of *E. coli* results by season at Loch na Keal

A statistically significant difference was found in mean *E. coli* result at Loch na Keal by season (one-way ANOVA, p = 0.008) (Appendix 4), with the mean in spring significantly lower than in summer and autumn.

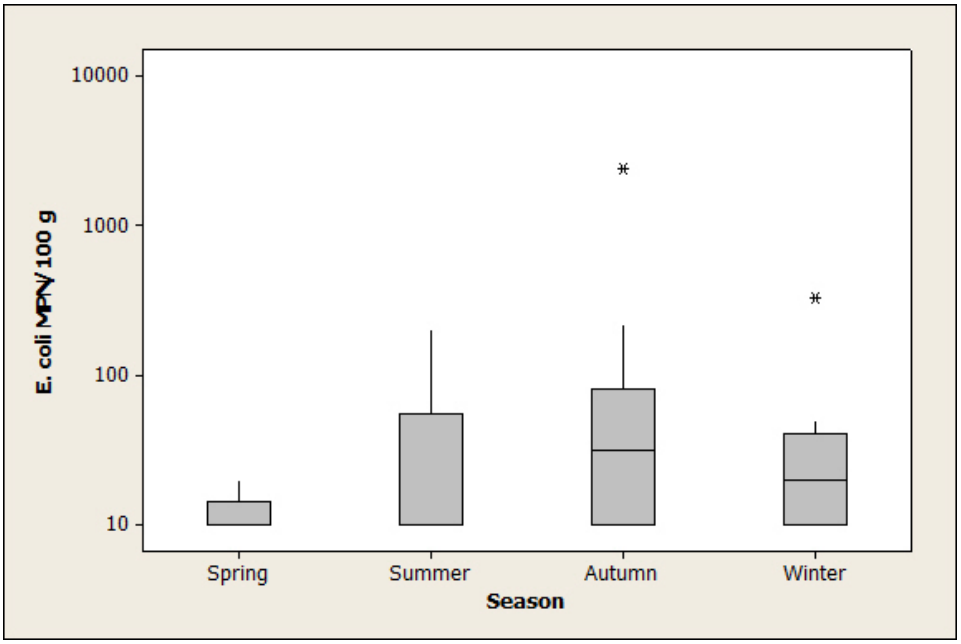


Figure 11.7 Boxplot of *E. coli* results by season at Loch na Keal West

A statistically significant difference was found in mean *E. coli* result at Loch na Keal West by season (one-way ANOVA, p = 0.011) (Appendix 4), with the mean in autumn higher than in spring.

11.6 Analysis of results against environmental factors

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

11.6.1 Analysis of results by recent rainfall

The nearest weather station with available rainfall data was at Gruline, approximately 7 km east of Loch na Keal. Rainfall data was purchased from the UK Meteorological Office for the period of 01/01/08 - 31/12/2013 (total daily rainfall in mm). Data was extracted from this for all sample results at Loch na Keal between 01/01/2008 – 31/12/2013.

Two-day rainfall

Scatterplots of *E. coli* results against total rainfall recorded on the two days prior to sampling for Loch na Keal and Loch na Keal West are displayed in Figures 11.8 and 11.9 respectively. Rainfall was available for 61 out of the 67 Loch na Keal results and 66 out of the 68 Loch na Keal West results. Jittering was applied to results in both figures at 0.02 (x-axis) and 0.001 (y-axis) respectively.

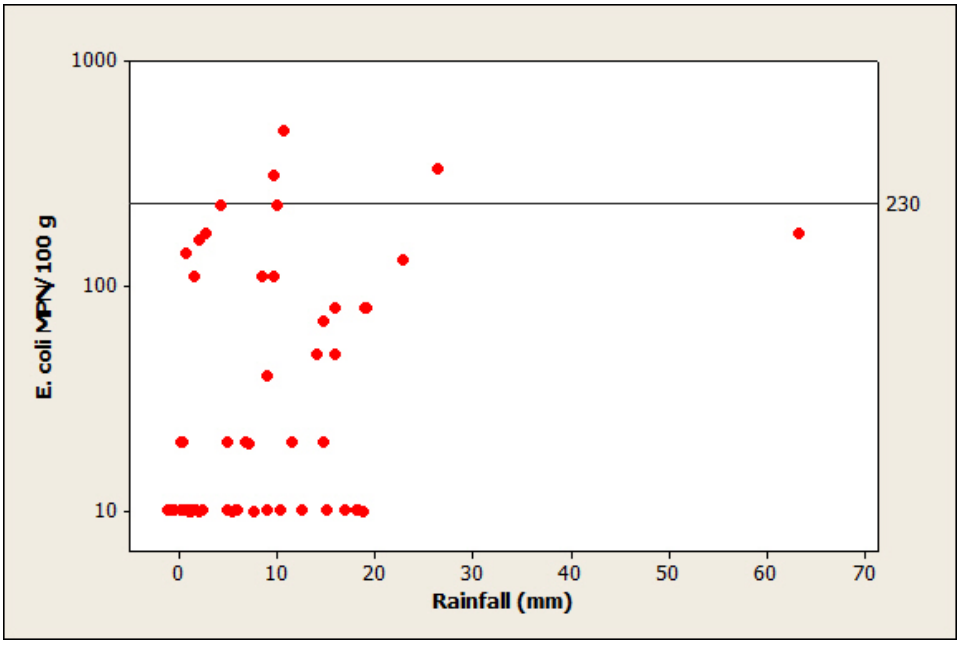


Figure 11.8 Scatterplot of *E. coli* results against rainfall in the previous two days at Loch na Keal

A significant correlation was found between *E. coli* results for Loch na Keal and the previous two day rainfall (Spearman's rank correlation r = 0.431, p = 0.001). Results

>230 *E. coli* MPN/100 g were associated with rainfall exceeding 8 mm in the two days prior to sampling.

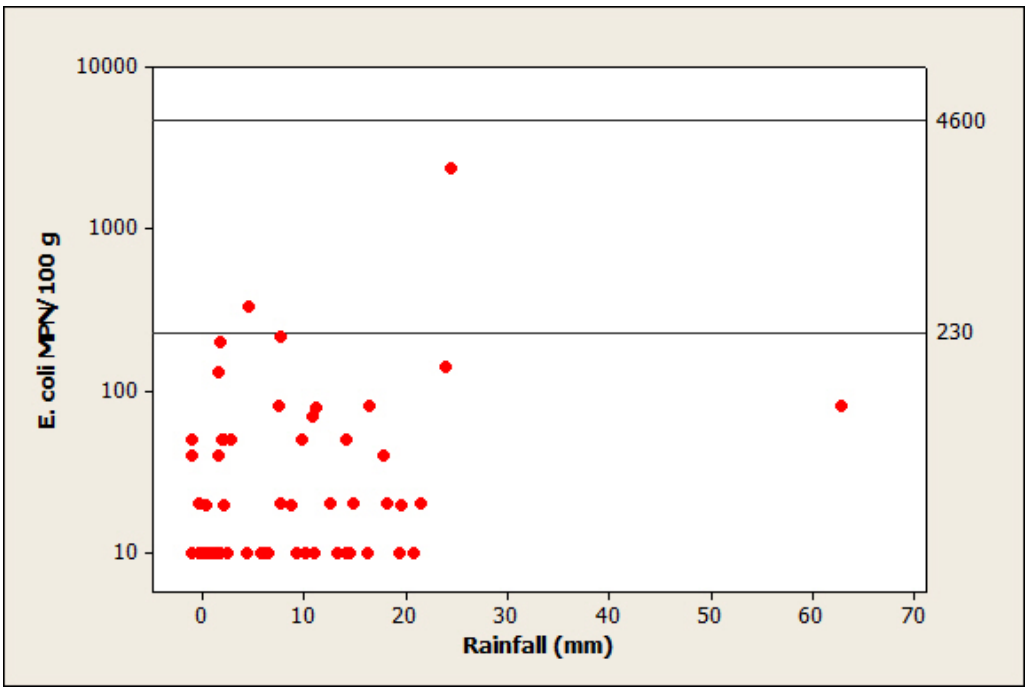


Figure 11.9 Scatterplot of *E. coli* results against rainfall in the previous two days at Loch na Keal West

A significant correlation was found between *E. coli* results at Loch na Keal West and the previous two day rainfall (Spearman's rank correlation r = 0.341, p = 0.007). The two results >230 *E. coli* MPN/100 g occurred at very different rainfall levels of 5.7mm and 25.2 mm in the two days prior to sampling.

Seven-day rainfall

The effects of heavy rainfall may take differing amounts of time to be reflected in shellfish sample results in different system, the relationship between rainfall in the previous seven days and sample results was investigated in an identical manner to the above. Scatterplots of *E. coli* results against total rainfall recorded for the seven days prior to sampling at Loch na Keal and Loch na Keal West are shown in Figures 11.10 and 11.11 respectively. Rainfall values were only available for 61 sampling occassions for Loch na Keal and 62 sampling occassions for Loch na Keal West. Jittering was applied to results in both figures at 0.02 (x-axis) and 0.001 (y-axis) respectively.

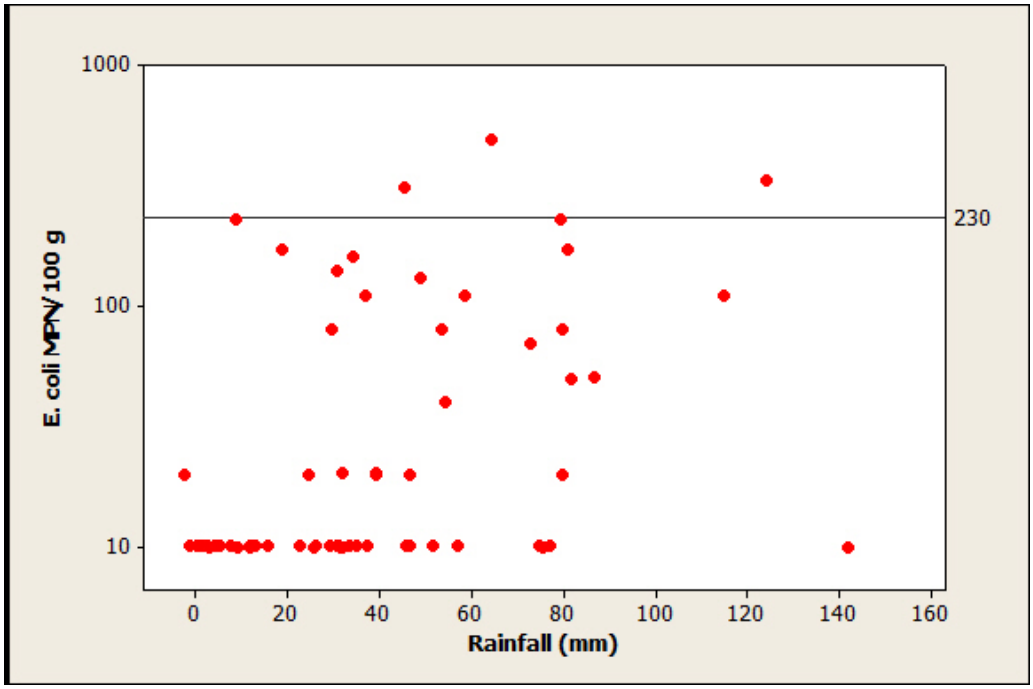


Figure 11.10 Scatterplot of *E. coli* results against rainfall in the previous seven days at Loch na Keal

A significant correlation was found between *E. coli* results and the previous seven day rainfall (Spearman's rank correlation r = 0.450, p = 0.000). Results >230 *E. coli* MPN/100 g were associated with rainfall levels exceeding 40 mm over the seven days prior to sampling.

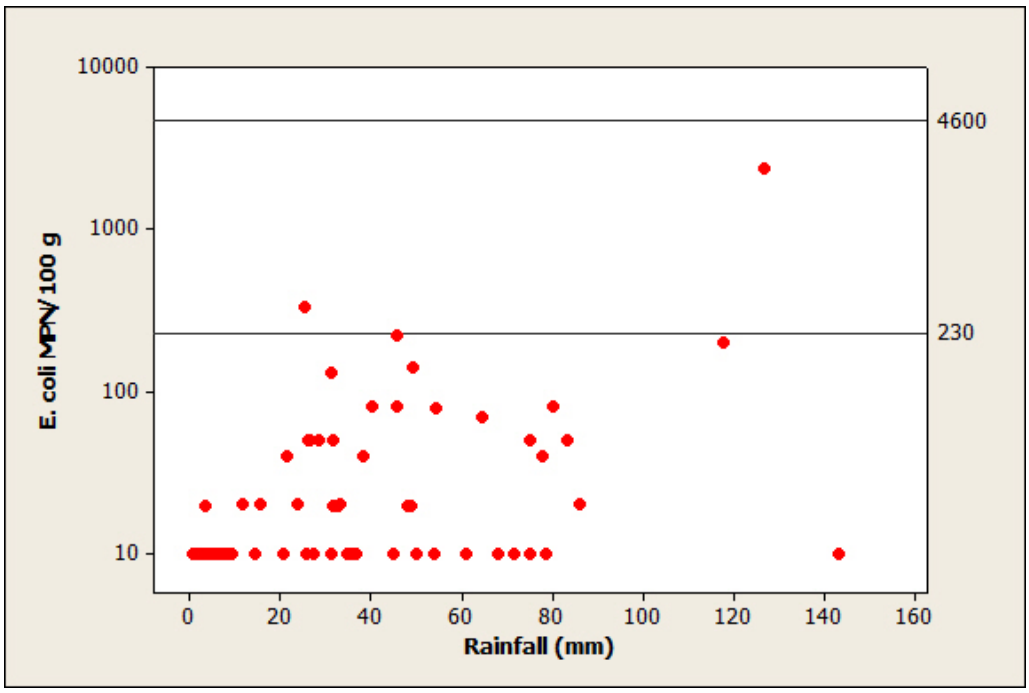


Figure 11.11 Scatterplot of *E. coli* results against rainfall in the previous seven days at Loch na Keal West

A significant correlation was found between *E. coli* results and the previous seven day rainfall (Spearman's rank correlation r = 0.350, p = 0.005). Results >230 *E. coli*

MPN/100 g were associated with rainfall levels exceeding 20 mm over the seven days prior to sampling.

11.6.2 Analysis of results by tidal cycles

Spring/neap tidal cycle

Spring tides are large tides that occur fortnightly and are influenced by the state of the lunar cycle. They reach above the mean high water mark and therefore increase circulation and particle transport distances from potential contamination sources on the shoreline. The largest (spring) tides occur approximately two days after the full/new moon, at about 45^{o} on a polar plot. The tides then decrease to the smallest (neap) tides, at about 225^{o}, before increasing back to spring tides. Polar plots of *E. coli* results against the lunar cycle are shown for Loch na Keal and Loch na Keal West in Figures 11.12 and 11.13 respectively**.** It should be noted local meteorological conditions (e.g. wind strength and direction) can also influence tide height, but is not taken into account in this section.

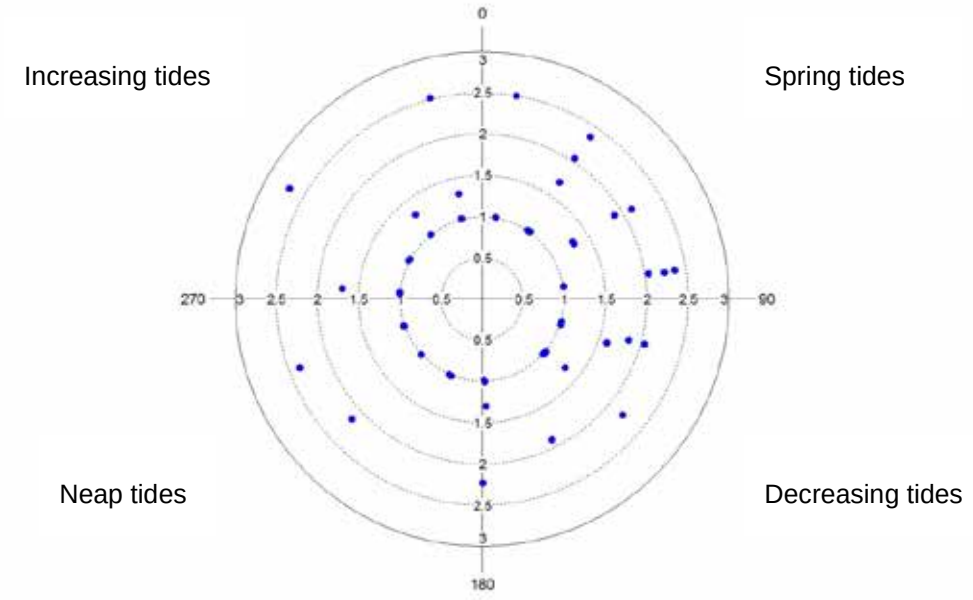


Figure 11.12 Polar plot of log_{10} *E. coli* results at Loch na Keal against the spring/neap tidal cycle

No significant correlation was found between log_{10} *E. coli* results at Loch na Keal and the spring/neap tidal cycle (circular-linear correlation r = 0.138, p = 0.298).

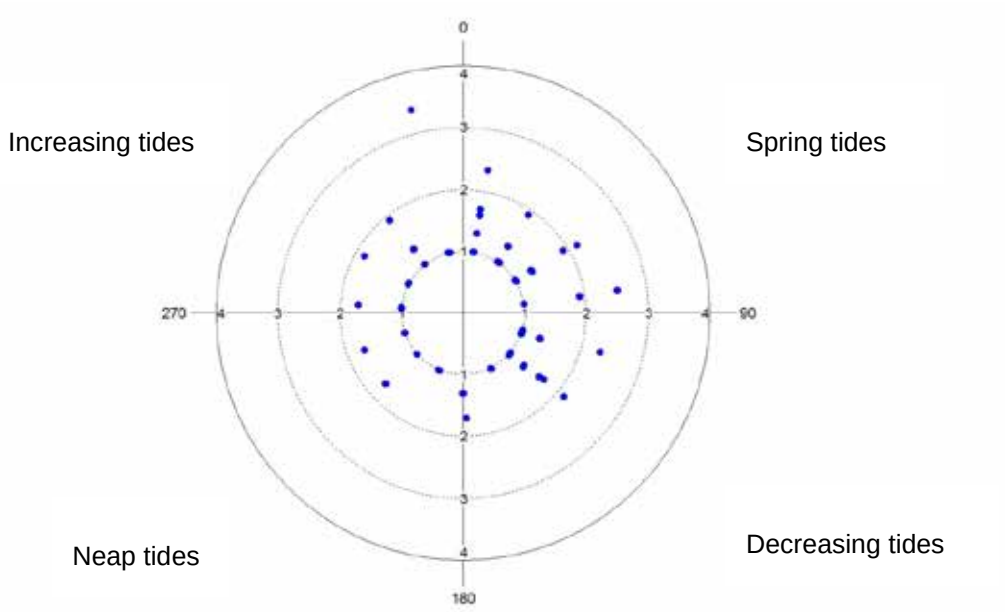


Figure 11.13 Polar plots of log_{10} *E. coli* results at Loch na Keal West against the spring/neap tidal cycle

No significant correlation was found between log_{10} *E. coli* results at Loch na Keal West and the spring/neap tidal cycle (circular-linear correlation r = 0.18, p = 0.121).

High/low tidal cycle

The tidal state (high/low tide) changes the direction and strength of water flow around production areas. Depending on the location of contamination sources, tidal state may cause marked changes in water quality near the vicinity of the farms. Shellfish species response time to *E. coli* levels can vary from within an hour to a few hours. Polar plots of *E. coli* results against the high/low tidal cycle for Loch na Keal and Loch na Keal West are shown in Figures 11.14 and 11.15 respectively. High water is located at 0^o on the polar plot and low water at 180^o.

High and low water data from Ulva was extracted from POLTIPS-3 in February 2014. This site was the closest to the production area (approximately 4 km to the northwest) and it is assumed that the tidal state will be similar between sites.

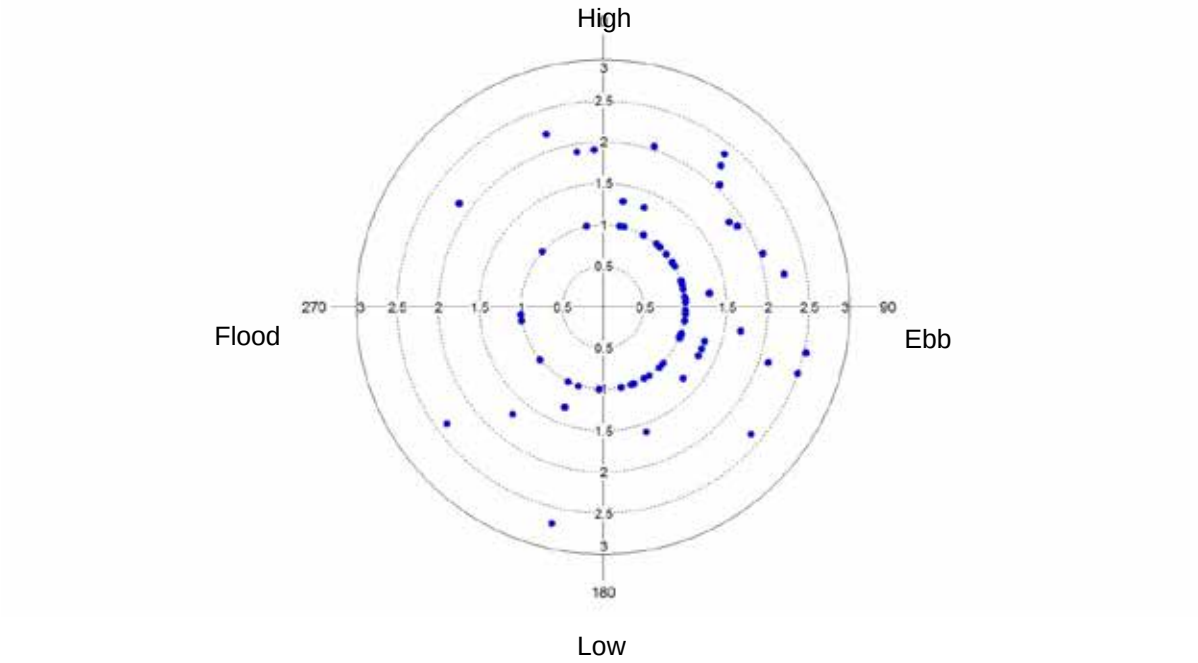


Figure 11.14 Polar plots of log_{10} E. coli results at Loch na Keal against the high/low tidal cycle

No significant correlation was found between log_{10} *E. coli* results at Loch na Keal and the high/low tidal cycle (circular-linear correlation r = 0.137, p = 0.302).

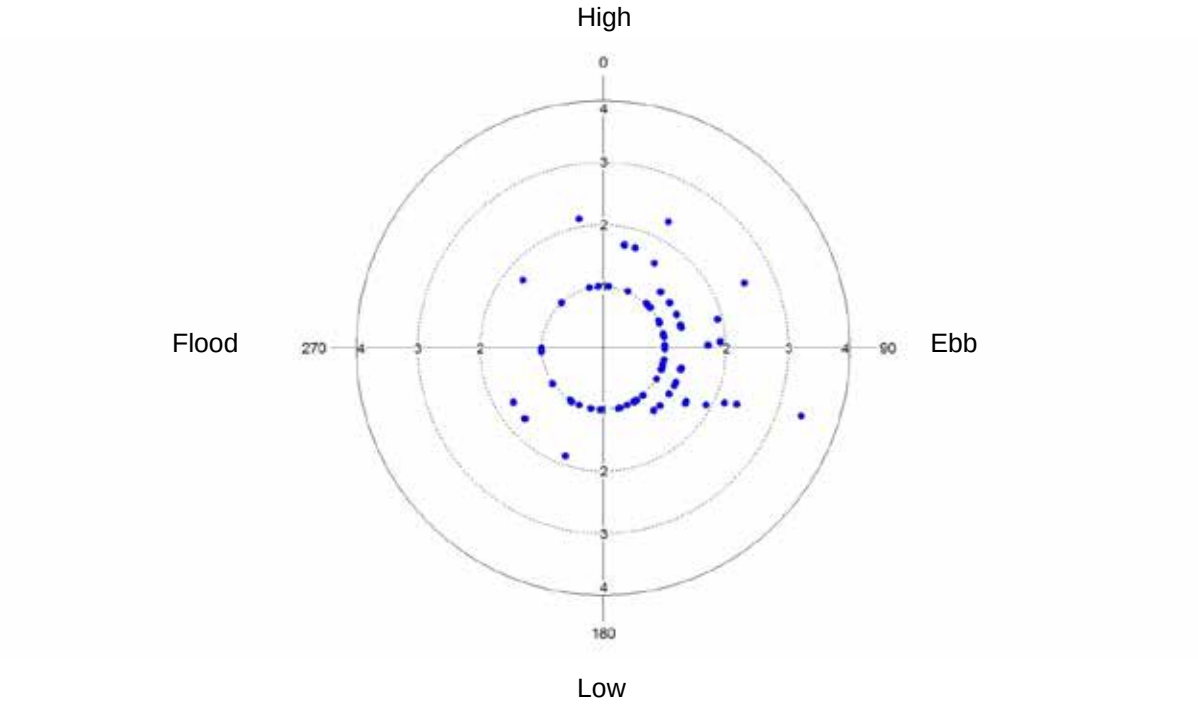


Figure 11.15 Polar plots of log_{10} *E. coli* results at Loch na Keal West against the high/low tidal cycle

No significant correlation was found between log_{10} *E. coli* results at Loch na Keal West and the high/low tidal cycle (circular-linear correlation r = 0.171, p = 0.151). A

number of samples appear to have been taken at around high tide, when the trestles would be expected to be under water. The RMP lies relatively far down the shoreline and therefore the reason for this error is not clear.

11.6.3 Analysis of results by water temperature

Water temperature can affect survival time of bacteria in seawater (Burkhardt, *et al*., 2000). It can also affect the feeding and elimination rates in shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. Water temperature is obviously closely related to season. Any correlation between temperatures and *E. coli* levels in shellfish flesh may therefore not be directly attributable to temperature, but to the other factors e.g. seasonal differences in livestock grazing patterns. Scatterplots of *E. coli* results against water temperature for Loch na Keal and Loch na Keal West are shown in Figures 11.16 and 11.17 respectively. Water temperature was recorded for 66/67 Loch na Keal samples, and 67/68 samples from Loch na Keal West. Jittering of results was applied at 0.02 (x-axis) and 0.001 (y-axis) respectively.

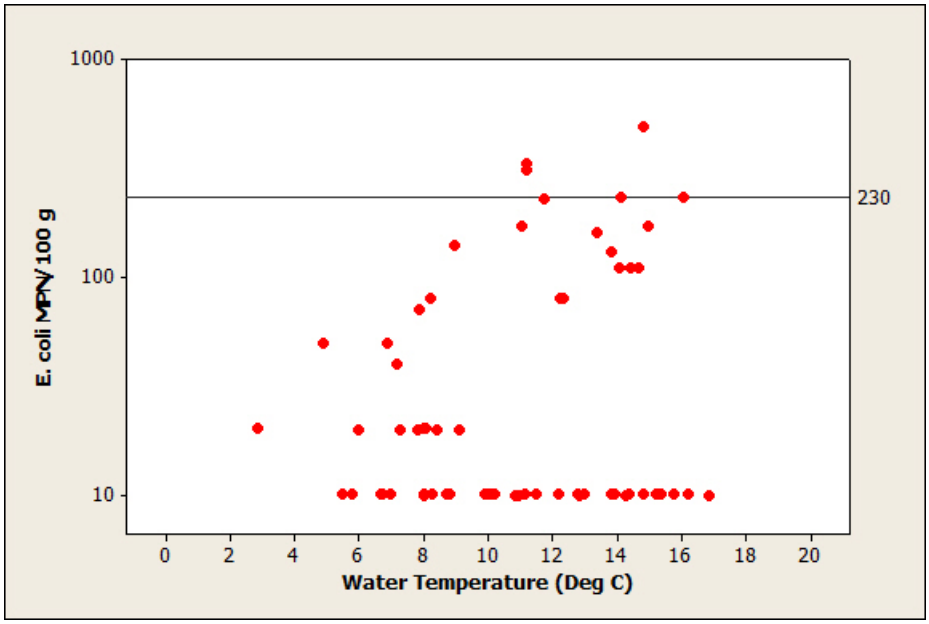


Figure 11.16 Scatterplot of *E. coli* results against water temperature at Loch na Keal

No significant correlation was found between *E. coli* results and water temperature at Loch na Keal (Spearman's rank correlation r = 0.133, p = 0.286), though the results at or above 230 *E. coli* MPN/100 g had recorded water temperatures greater than 10^{o}C.

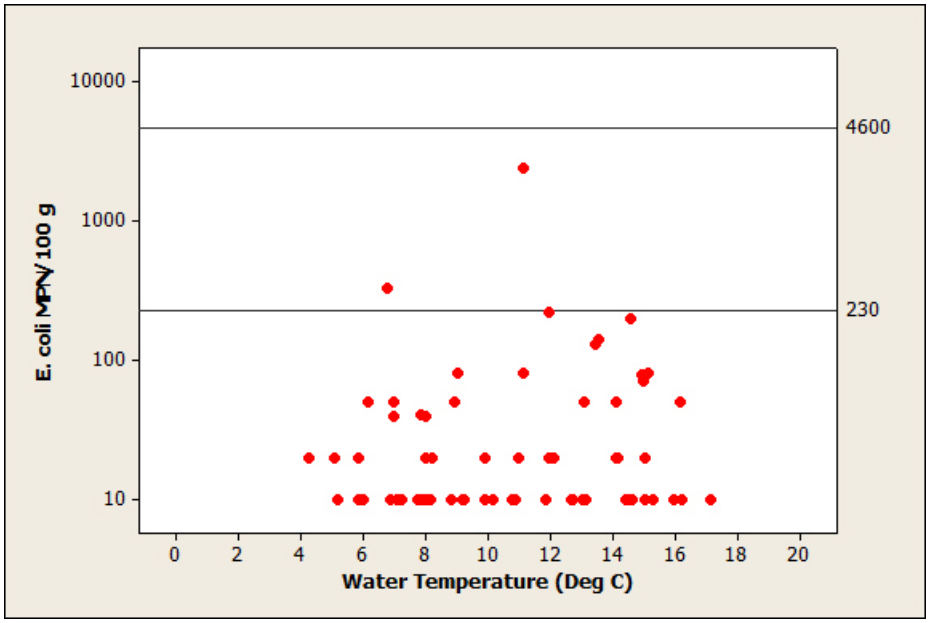


Figure 11.17 Scatterplot of *E. coli* results against water temperature at Loch na Keal West

No significant correlation was found between *E. coli* results and water temperature (Spearman's rank correlation r = 0.097, p = 0.435) at Loch na Keal West.

11.6.4 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence and hence freshwater-borne contamination at a site. Scatterplots of *E. coli* results against salinity for Loch na Keal and Loch na Keal West are shown in Figure 11.18 and Figure 11.19, respectively. Salinity was recorded for 46/67 Loch na Keal samples, and 46/68 samples from Loch na Keal West. Jittering of results was applied at 0.02 (x-axis) and 0.001 (y-axis) respectively.

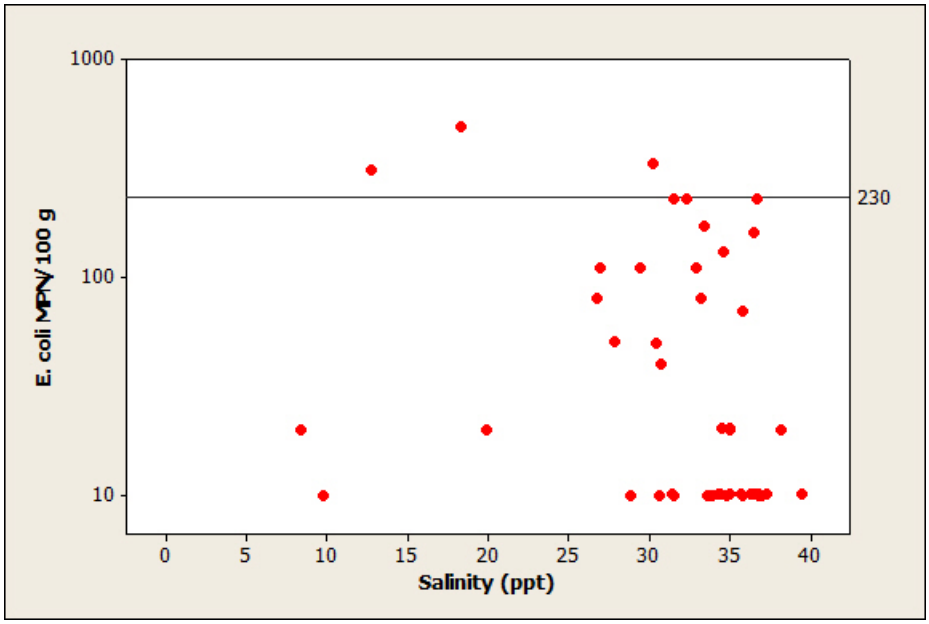


Figure 11.18 Scatterplot of *E. coli* results against salinity at Loch na Keal

A statistically significant negative correlation was found between *E. coli* results at Loch na Keal and salinity (Spearman's rank correlation r = -0.375, p = 0.010). Results >230 *E. coli* MPN/100 g occurred across a broad range of salinities (12.5 to 30 ppt), however results below the limit of detection occurred mainly at higher salinities.

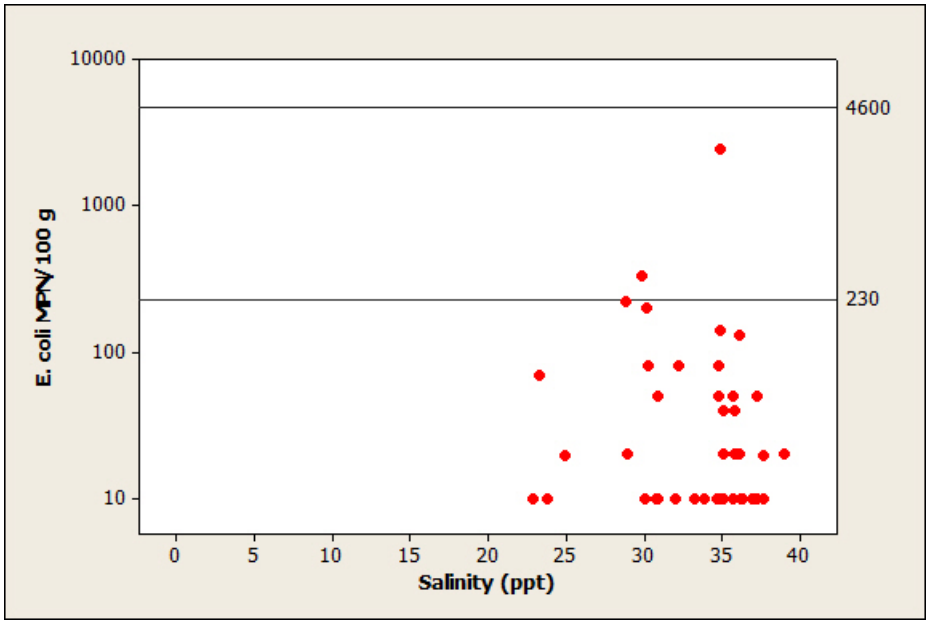


Figure 11.19 Scatterplot of *E. coli* results against salinity at Loch na Keal West

No significant correlation was found between Pacific oyster *E. coli* results at Loch na Keal West and salinity (Spearman's rank correlation r = -0.161, p = 0.284), with the majority of samples taken at >30 ppt.

11.7 Evaluation of results over 230 *E. coli* MPN / 100g

In the results from Loch na Keal, three Pacific oyster samples had results >230 *E. coli* MPN/100 g and these are listed in Table 11.2.

Table 11.2 Loch na Keal historic sampling results over 230 *E. coli* MPN/100g

Collection Date	*E. coli* (MPN/100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (°C)	Salinity (ppt)	Tidal state (spring/neap)	Tidal State (high/low)
14/10/2008	310	NM 4741 3929	8.8	47.9	11	13	Spring	Ebb
18/08/2009	490	NM 4742 3929	10.1	62.4	15	18	Increasing	Low
11/10/2011	330	NM 4743 3930	25.2	125.3	11	30	Increasing	Ebb

High results were taken in months August and October, from locations within less than 100 m from the RMP. Rainfall levels were relatively high over the previous two and seven days. Samples were taken across a wide range of salinities and at water temperatures greater than 10°C. They were taken at increasing or spring tides and during ebb or low tide.

In the results from Loch na Keal West, two Pacific oyster samples had results >230 *E. coli* MPN/100 g and are listed below in Table 11.3.

Table 11.3 Loch na Keal West historic sampling results over 230 *E. coli* MPN/100g

Collection Date	*E. coli* (MPN/100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (^{o}C)	Salinity (ppt)	Tidal state (spring/neap)	Tidal State (high/low)
02/02/2010	330	NM 4583 3891	5.7	23.2	6.5	30	Spring	Ebb
11/10/2011	2400	NM 4585 3891	25.2	125.3	11	35	Increasing	Ebb

High results were taken in months February and October from within <20 m of each other and the RMP. Rainfall levels have been relatively high over the previous two and seven days, with the highest associated with the highest result. Samples were taken at varying temperatures and salinities, and at increasing or spring tides.

Summary and conclusions

Overall, no statistically significant difference was found in *E. coli* monitoring results between Loch na Keal and Loch na Keal West production areas.

Loch na Keal

Sample results have decreased over time, with results since 2012 all reported as <100 *E. coli* MPN/100 g. A strong seasonal increase in results was noted between June and November, with two of the three highest results (>230 *E. coli* MPN/100 g) taken in October. A statistically significant correlation between results and season was found, with higher results in summer and autumn compared to spring. Statistically significant correlations were noted between results and previous two day and seven day rainfall, and a significant negative correlation was found with salinity. No significant correlation was found between results and water temperature, or spring/neap and high/low tidal states.

Loch na Keal West

Overall sampling results were consistently low, with many of the sample results below the limit of detection. Results were lowest from March to May, and a statistically significant difference was found by season, with results significantly higher in autumn than in spring. Statistically significant correlations were noted between results and previous two day and seven day rainfall. No significant correlation was found between results and water temperature or results and salinity. No correlations were noted between results and spring/neap or high/low tidal states.

12. Designated Waters Data

Shellfish Water Protected Areas

The Shellfish Waters Directive (2006/113/EC) was repealed in 2013. Equivalent protection for areas previously designated under that Directive is currently given under The Water Environment (Shellfish Water Protected Areas: Environmental Objectives etc.) (Scotland) Regulations 2013. The Isle of Ulva, Mull (Loch Tuath) Shellfish Water Protected Area (SWPA) is an extension of the previous Isle of Ulva, Mull (Loch Tuath) Shellfish Growing Water (SGW), which only covered Loch Tuath and the north west corner of Loch na Keal. The SWPA designation covers the majority of Loch Tuath and Loch na Keal, including both Loch na Keal shellfisheries. There is an historic SGW monitoring point located in Loch Tuath at NM 453 410. Since 2007, SEPA has used the FSAS *E. coli* data for assessing microbiological quality. This data has already been assessed for Loch na Keal and Loch na Keal West in Section 11 and is therefore not covered again here. The designated SWPA for Loch na Keal is shown in Figure 12.1.

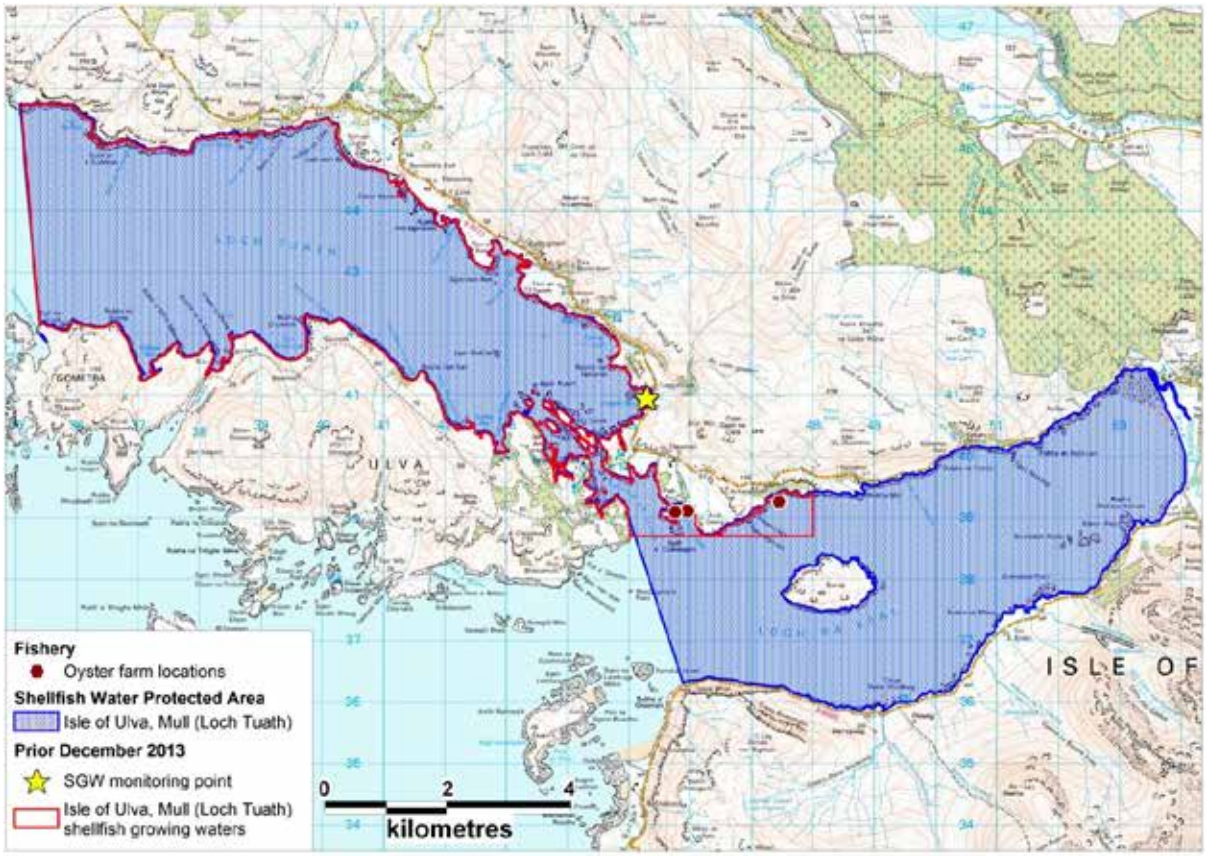


Figure 12.1 Designated shellfish water protected area – Isle of Ulva, Mull (Loch Tuath)

Bathing Waters

There are no designated bathing waters within Loch na Keal.

13. Hydrographic Section

13.1 Introduction

The Study Area

Loch na Keal is situated on the west coast of the Isle of Mull in Argyll and Bute District of the west coast of Scotland. The surrounding area is mountainous, and lies in a sparsely populated region away from industrial activities and agriculture. The River Bà and other small rivers including Scarisdale River, Abhainn na h-Uama, Abhainn Dhiseig, and Abhainn Doire Dhubhaig flow into the loch. Loch na Keal is bordered on all sides by the B8073.

The assessment area encompasses the central portion of Loch na Keal surrounding the Isle of Eorsa and includes a portion of the Sound of Ulva. It is shown in Figure 13.1 with the assessment area demarcated by the red lines. The total length of Loch na Keal is 10.7 km (Edwards & Sharples, 1986), while the study area is approximately 6 km long and on average 3 km wide.

Coordinates for Loch na Keal:

56.465241°N 006.089172°W

OS Grid Reference NM 48214 37843

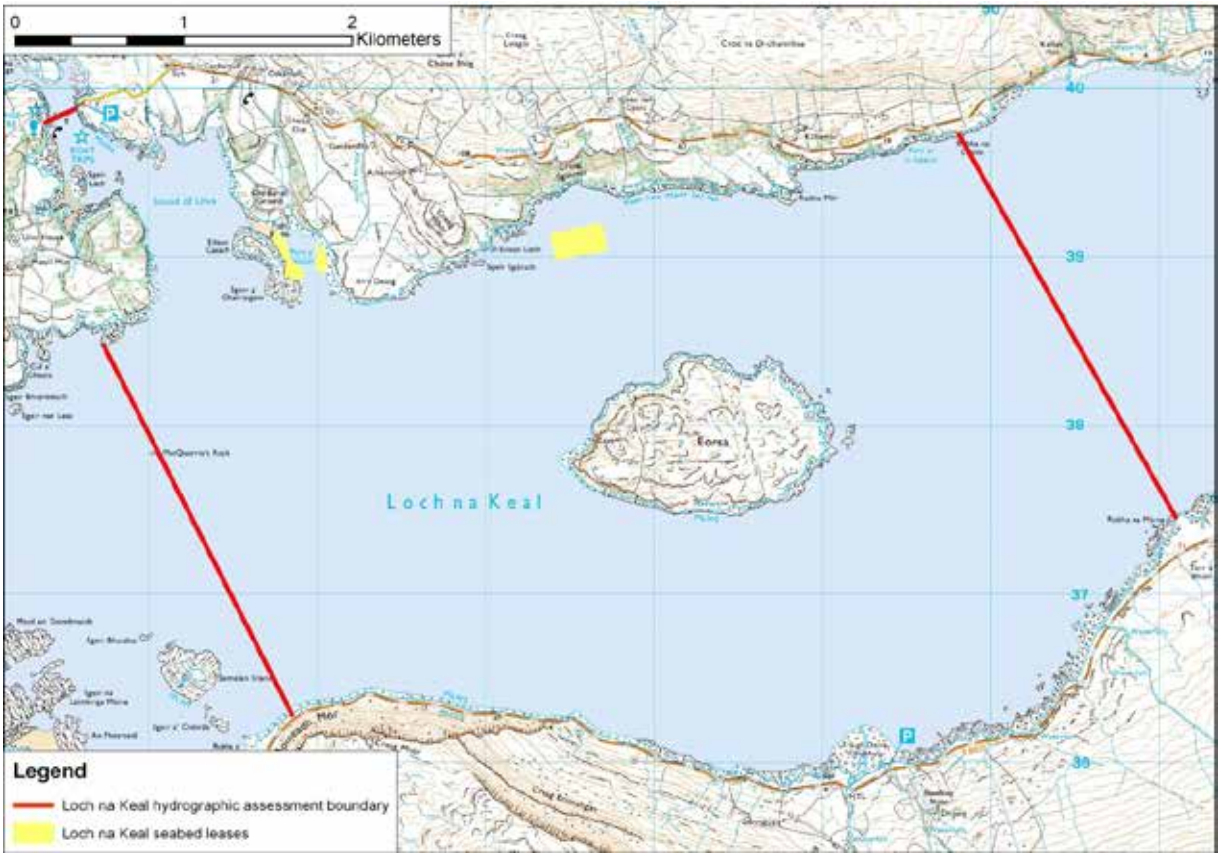


Figure 13.1 Extent of the hydrographic study area

13.2 Bathymetry and Hydrodynamics

13.2.1 Bathymetry

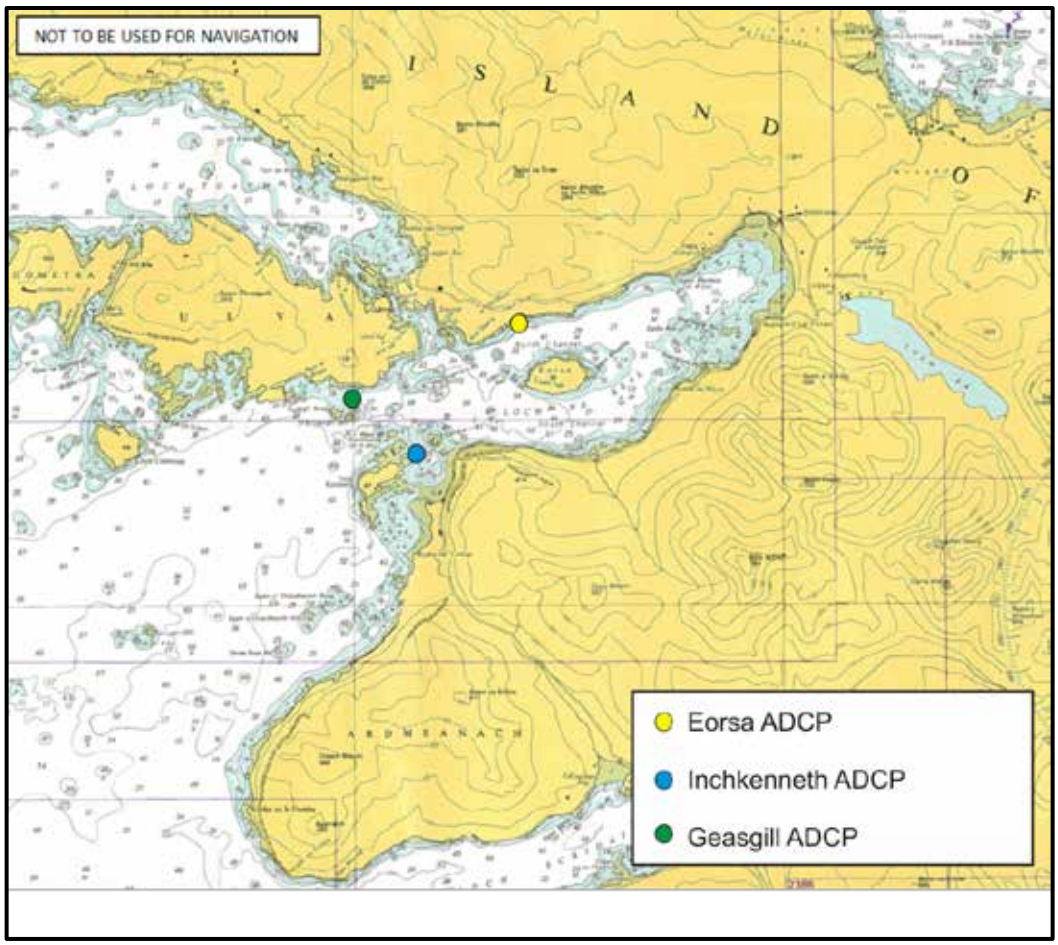


Figure 13.2 Admiralty chart (2652, Edition 4 year 2013) extract for Loch na Keal. ADCP stations within (Eorsa) and outside the assessment area (Inchkenneth and Geasgill) are shown.

Figure 13.2 shows the bathymetry of Loch na Keal. In general, the bathymetry slopes gently from a sand and shingle beach at the head of the loch to deeper water at the mouth of the loch (approximately 55 m). Shallower water can be found around the Isle of Eorsa and within the Sound of Ulva, ranging from 5 to 15 m in depth. There is one isolated deep area of 124 m, adjacent to the tidally exposed MacQuarries's Rock on the western boundary of the assessment area. The mean depth at low water for the loch is 26 m, while the estimated low water volume is 7.95 x 10^8 m^3 (Edwards & Sharples, 1986)

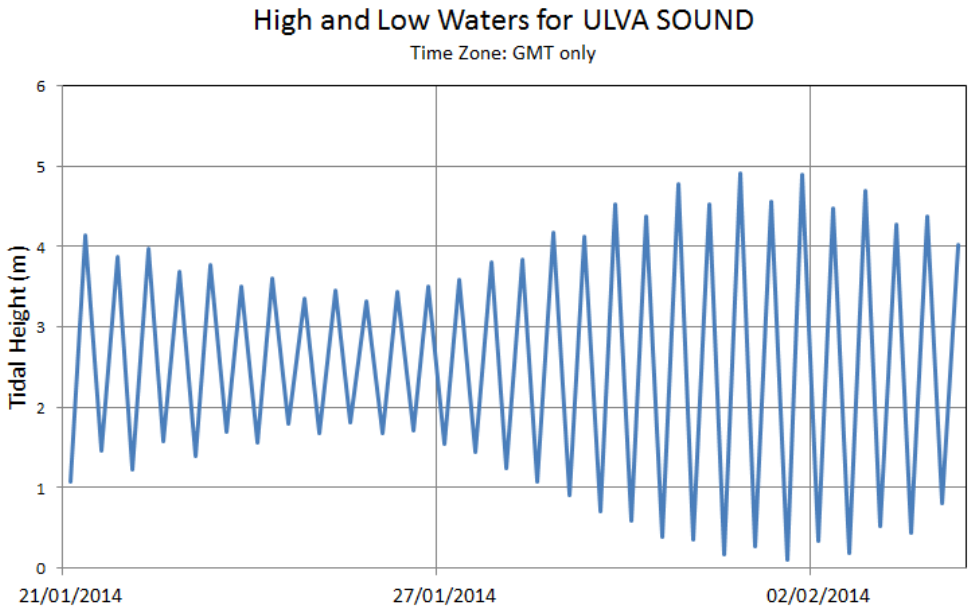
There is one sill in the loch characterised by many shallows and islands (Edwards & Sharples, 1986). It is 1.45 km in length and has an average depth of 24 m. This sill lies approximately 1 km west of the assessment area.

The Sound of Ulva is relatively narrow and shallow and we do not consider this to be a significant pathway for transport into or out of the assessment area.

13.2.2 Tides

Loch na Keal has a typical semi-diurnal tidal characteristic. Data on tidal information is given from charted information. The nearest location for tidal predictions is Ulva Sound, Loch na Keal [http://easytide.ukho.gov.uk].

Standard tidal data for Ulva Sound, Loch na Keal, centred around the survey date of January 28th 2014, is shown in Figure 13.3.



Reproduced from Poltips3 [www.pol.ac.uk/appl/poltips3]

Figure 13.3 Two week tidal curve for Ulva Sound, Loch na Keal.

Tidal Heights at Ulva Sound, Loch na Keal:

Mean High Water Springs = 4.40 m
Mean Low Water Springs = 0.60 m
Mean High Water Neaps = 3.20 m
Mean Low Water Neaps = 1.80 m

Tidal Ranges:

Mean Spring Range = 3.80 m
Mean Neap Range = 1.40 m

This gives a tidal volume of water within the assessment area during each tidal cycle of approximately:

Springs: 1.1×10^8 m^3
Neaps: 4.3×10^7 m^3

13.2.3 Tidal Streams and Currents

There are no published tidal diamonds for this area. Enhancement of tidal streams caused by straights and shallow areas will be important around islands along the sill adjacent to the western boundary of the assessment area, Inch Kenneth, Geasgill Mor, Geasgill Beag, and Samalan Island, which may cause localised effects.

Current meter data was available at one site within the assessment area. Data were obtained from SEPA from a site on the northern coast of Loch na Keal to the north of Eorsa, shown in Figure 13.2 and 13.4. This survey spanned a 22 day period (Compass Data System Ltd, 2003).

Current meter data were also obtained from SEPA at two sites adjacent to the western boundary of the assessment area at Geasgill and Inchkenneth (Anderson, 2008; Anderson, 2006). Each of these hydrographic surveys spanned 15 days; this being the half-lunar period to capture a spring-neap cycle. These sites are shown in Figure 13.2.

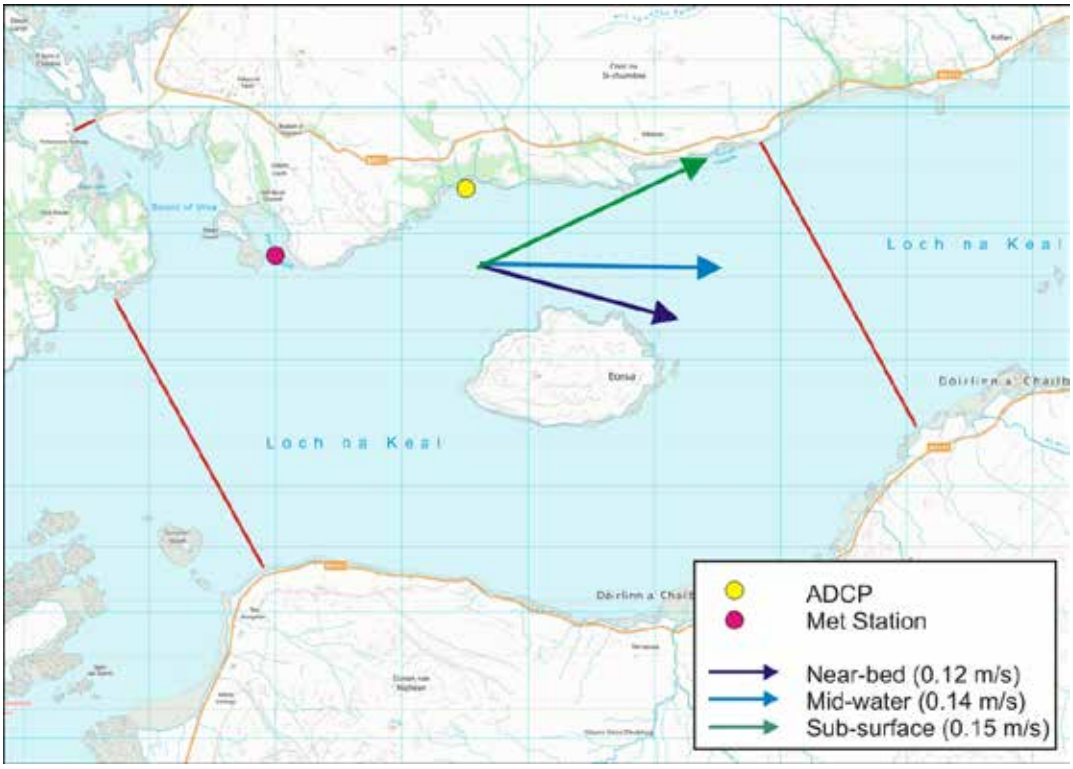


Figure 13.4 Map showing Loch Na Keal sample sites within the assessment area.
Using the principal current amplitude at each measured depth and the assumption of a uniform sinusoidal tide, the cumulative transport distance and direction that might be expected during each phase of the tide is shown above. Residual transport was determined to be negligible.

Data from Eorsa, at the northern edge of the Loch Na Keal assessment area, 147574, 739225 (OSGB) were collected between 05/12/2001 and 27/20/2001 and are summarised in Table 13.1.

Table 13.1 Eorsa current data measured in 2001

Approximate Height/Depth	Near-bed (3 m above seabed)	Mid-water (12 m below surface)	Sub-surface (5 m below surface)
Mean Speed (ms^{-1})	0.03	0.03	0.04
Maximum Speed (ms^{-1})	0.16	0.14	0.17
Principal Axis Amp & Dir (ms^{-1}) & (^oM)	0.12 (105.6)	0.14 (90.7)	0.15 (64.6)
Residual speed (ms^{-1})	0.01	0.01	0.01
Residual direction (^oM)	292	288.3	349.8

Data from Geasgill, OSGB 143657 737678 and adjacent to the study area, were collected between 28/05/2008 and 12/06/2008 and are summarised in Table 13.2. The report states that this site was characterised by moderately high tidal energy, with 'similarity' between tidal current velocity and direction over the water column (Anderson, 2008). Velocities were moderately high, with a maximum surface current of 0.283 ms^{-1}. The record of current speed showed a clear semi-lunar periodicity and spring-neap variation.

Table 13.2 Geasgill current data measured in 2008

Approximate Height/Depth	Near-bed (2 m above seabed)	Mid-water (14 m below surface)	Sub-surface (6.8 m below surface)
Mean Speed (ms^{-1})	0.028	0.086	0.088
Maximum Speed (ms^{-1})	0.228	0.269	0.283
Principal Axis Amp & Dir (ms^{-1}) & (^oM)	0.064 (255)	0.135 (265)	0.137 (265)
Residual speed (ms^{-1})	0.010	0.015	0.012
Residual direction (^oM)	066	176	244

Residual current directions were strongly asymmetric at all depths, oriented towards the north-east at the seabed, the south at mid-water, and the south-west at the surface. Although weak, virtually negligible, it is possible that surface residual flow is driven by freshwater flow at the surface from the River Bà and other smaller rivers, or flow associated with the nearby Sound of Ulva. Alternatively it could be a response of the surface to east/north-east wind forcing, although no wind directions are reported for the data.

Data from Inchkenneth, just outside the assessment area at OSGB 144877 736581, were collected between 06/06/2006 and 21/06/2006 and are summarised in Table 13.3. The site was characterised by low tidal energy and little similarity between current velocity and direction over the water column. While velocities were generally low, the maximum recorded velocity was 0.279 ms^{-1}. The velocities show a degree of

semi-lunar periodicity and spring-neap variation (Anderson, 2006). Mid-water and near bed current directions were strongly symmetric, and residual currents oriented to the south and the south-east, respectively. Sub-surface current directions showed greater variance over the tidal cycle, though residual currents at this depth were oriented to the north-east.

Table 13.3 Inchkenneth current data measured in 2006

Approximate Height/Depth	Near-bed (2 m above seabed)	Mid-water (14 m below surface)	Sub-surface (4.3 m below surface)
Mean Speed (ms^{-1})	0.025	0.037	0.053
Maximum Speed (ms^{-1})	0.190	0.153	0.279
Principal Axis Amp & Dir (ms^{-1}) & (^oM)	0.059 (165)	0.059 (175)	0.066 (345)
Residual speed (ms^{-1})	0.008	0.022	0.007
Residual direction (^oM)	140.01	185.76	23.84

In general, the data from these locations indicate rather moderate to weak flows and SEPA summary data has classified the Eorsa data has being highly quiescent.

Using a typical surface principal current and assuming a uniform sinusoidal tide, the cumulative transport that might be expected during each phase of the tide (approximately 6 hours) has been estimated for each measurement site as: Eorsa, approximately 2.0 km (based on a principal current amplitude of 0.15 m/s); Geasgill, approximately 1.8 km (based on a principal current amplitude of 0.137 m/s); Inchkenneth, approximately 0.9 km (based on a principal current amplitude of 0.066). No distinction is made here for springs and neaps.

Dispersion is an important property of a water body with respect to redistribution of contaminants over time. There are no measurements or published data relating to dispersion in Loch Na Keal. Without such data it is difficult to judge what the dispersive environment might be like. However, flow round Eorsa in the centre of the assessment area, through the Sound of Ulva, and around the islands at the sill adjacent to the western boundary of the assessment area might enhance dispersion.

Dispersion of surface contaminants may be enhanced by wave energy within Loch Na Keal. Sources of wave energy are from both short period waves that are created within the Loch itself and longer period swells originating from the North Atlantic Ocean.

13.2.4 River/Freshwater Inflow

One main river, the River Bà, flows into Loch Na Keal from Loch Bà. This river enters Loch Na Keal just outside the study area at the eastern end of the loch. Numerous other small rivers flow into the study area from the surrounding hillsides. These

include the Allt Mor to the north of the loch, and Abhainn Doire Dhubhaig, Abhainn na h-Uamha, and the Scarisdale River to the south, as well as a number of smaller burns. The annual precipitation in the area is approximately 2000 mm and the annual freshwater runoff is estimated as 250 Mm^3yr^{-1} (Edwards & Sharples, 1986). The ratio of fresh water flow to tidal flow is low at approximately 1:250 (Edwards & Sharples, 1986), though of course this will have seasonal variability.

13.2.5 Meteorology

The nearest weather station for which a near complete rainfall dataset is available is located at Gruline, situated approximately 7 km to the east. Rainfall records are available from January 2007 to December 2012.

The highest rainfall for this time period occurred in 2011, while 2010 generally had the lowest daily rainfall. Though high rainfall values (> 30 mm/d) were recorded in every year, an exceptionally high rainfall event of nearly 80 mm/d occurred in 2011. The highest daily rainfall values occurred in autumn and winter, between the months of August and February. Daily rainfall at Gruline peaks in November, and the 2011 extreme rainfall event occurred during this month. For the duration of the data set, daily rainfall of below 1 mm occurred on 42% of days, while daily rainfall above 10 mm occurred on 21% of days.

It can be surmised from these data that run-off due to rainfall is expected to be higher in the autumn and winter months but it must also be noted that high rainfall and consequently high run-off can occur in most months.

Wind data were collected from Tiree, located approximately 46 km to the west of the assessment area. Given the distance between these two locations, wind statistics may not be directly transferrable to the specific production area in Loch Na Keal. They can, however, be used to give a general pattern of the seasonal wind conditions in the middle Inner Hebrides area. Wind data from Tiree show that the predominant wind direction is from west/south-west to south/south-east. Winds were strongest between December and February from these directions. Northerly winds occurred frequently during the spring and summer, while easterly winds were least likely. Wind direction in Loch Na Keal is likely to be strongly influenced by the surrounding mountainous topography.

13.2.6 Model Assessment

The exchange characteristics of Loch Na Keal were assessed using a layered box model approach. The model represents the Loch as a box made up of three layers and was formulated according to the method of Gillibrand et al (2013). The box layers are forced with surface wind stress, estimates of fresh water discharge, surface heat flux parameters and, at the open coastal boundary, profiles of temperature and salinity are prescribed from climatology compiled by the UK

Hydrographic Office. This sets the model with climatological boundary conditions to represent an 'average' year. The model has been tuned and validated for Lochs Creran and Etive. A full validation for Loch Na Keal has not been done.

The box model quantifies the primary exchange mechanisms. The key outputs from the model with respect to this hydrographic assessment is a series of annual mean values that describe the relative importance of the estuarine (gravity) exchange, tidal exchange, and the flushing time, which is the inverse of the exchange rate. These values are given in Table 13.4.

Table 13.4 Summary of annual mean parameter values from the box modelling exercise.

Parameter	Value
Tidal Volume Flux ($m^3 s^{-1}$)	396
Estuarine Circulation Volume Flux ($m^3 s^{-1}$)	110
Median Flushing Time (days)	19.5
95%-ile Flushing Time (days)	30

The ratio of Tidal volume flux to estuarine circulation volume flux is 3.6. Values greater than 2 indicate a system that is strongly tidal in its exchange characteristics (Gillibrand, et al., 2013).

The exchange time for the surface and intermediate layers is calculated as 19.5 days compared to the tidal prism estimate of 4.3 days (Marine Scotland, 2012). The difference in calculated exchange times is due to mixing and recirculation processes not represented in the tidal prism method which tends to retain water behind the shallow sills.

13.3 Hydrographic Assessment

13.3.1 Surface Flow

The site and meteorological data indicate that the discharge of freshwater into the surface will occur primarily to the east of the assessment area; though there are a number of smaller rivers discharging around the perimeter of the assessment area. The meteorological data indicate a moderate seasonal variation in freshwater discharge.

The loch is relatively small such that there is unlikely to be much variation in properties of flow across the loch. Although the tidal flows are found to be rather weak, the shallow nature of the loch and mean that it is likely that the loch will be well mixed, particularly during periods of strong winds. However, during periods of high rainfall it is likely to develop a distinct surface layer.

From the current meter record on the north side of the assessment areas the tidal flow appears to be broadly aligned with the shore. We anticipate that the tidal flow would be similar on the east side, flowing into the loch on the flood and out of the

loch on the ebb. The cumulative transport distance on each phase (flood/ebb) of the tide has been estimated at around 2 km within the assessment area.

Residual flows are relatively weak, indicating that the estuarine circulation is rather weak in this area. However, surface residual flows would be enhanced by winds blowing out of the loch, from the east. Winds will also further enhance the mixing of the waters through the full depth. The topography of the land is likely to steer the wind along the axis of the loch enhancing the in/out flow of surface waters.

From the rather limited current meter measurements in Loch Na Keal it is likely that any surface contaminant in the inner part of the loch would be transported primarily along the shoreline. Once beyond the entrance there is likely to be effective transport and dispersal.

13.3.2 Exchange Properties

The flushing time for the whole loch complex using a simple tidal prism approach is around 4.3 days, Section 13.2.6, but this is probably an underestimation due to the nature of the sills which can retain water and therefore contaminants within the loch.

The box modelling has shown that a more realistic flushing time for the surface and intermediate depth waters within the assessment area is around 19.5 days. This would expect to be reduced during periods of strong down-loch winds from the east, which are relatively rare. Similarly, exchange rates may be reduced during strong up-loch winds from the west, which are considerably more prevalent. Therefore, one might describe the flushing characteristics for the surface waters of the assessment area as being ‘moderately flushed’, with the potential for reduced flushing efficiency due to prevailing winds.

There is a limited amount of available current meter data for Loch Na Keal and there is a paucity of measured hydrographic data. There is no descriptive literature on exchange properties for the area. However, it has a relatively simple geometry and we are able to make a broad assessment of the likely exchange rates and the impact of wind. Consequently, the confidence level of this assessment is MEDIUM.

14. Shoreline Survey Overview

The shoreline survey at Loch na Keal was conducted on the 28th and 29th of January 2014. Heavy rain fell during the 48 hours prior to the survey, though no rainfall was reported on either of the survey days.

Pacific oyster farms were identified at Eilean Liath (Loch na Keal) and Eilean Casach (Loch na Keal West). At Eilean Liath, oysters were grown in baskets suspended at approximately 2-4 m depth from longlines. At Eilean Casach, oysters were grown on trestles on two intertidal areas, one on the west side of Port a Chlaid where the main block of trestles is located and another, smaller area of damaged trestles on the east side of Port a Chlaid. The named harvester for both sites, Mr. Mawhinney, identified that he was awaiting the necessary permissions to expand production.

The surrounding land was noted to be sparsely inhabited. Isolated houses and farms were set back from the shoreline. Public toilets with an associated septic tank and two discharge pipes were located at the Ulva Ferry slipway, north of Eilean Casach. The harvester identified that there was a strong seasonal pattern to usage of the public toilets, with greatest use expected during summer when boats destined for Staffa and the Treshnish Isles set out from the pier.

Ulva ferry crossing includes a pier and a slipway. Approximately 20 moorings with a mixture of dinghies and two small fishing boats were observed at Ulva, whilst two fixed unoccupied moorings were located at Port a' Chlaidh. Two slipways and a floating pontoon associated with the fish farm base were noted near Eilean Casach. This is also used by the shellfish harvester Mr Mawhinney.

Eight sheep and 10 cows were observed during the survey, with sheep observed close to shoreline compared to the cows that were set back adjacent to the main road. Farms were noted to also be set back from the shoreline. The harvester stated sheep had been moved to a holding field nearer the main road several days prior to the survey.

The land immediately adjacent to the shore consists of grazed grassland, native woodland and bog around Eilean Casach, with steep rocky slopes and rough ground present around Eliean Liath. Inland, hillsides are a mixture of heath, moor and native woodland.

The largest watercourse found in the area was Allt na Criche, which discharged to the eastern shore of Port a' Chlaidh. The water sample taken from here returned a result at 330 *E. coli* cfu/100 ml. The majority of the other watercourses were small. Little wildlife was observed during the survey, with observations including 10 gulls, two crows, a heron and two oystercatchers, as well as a young otter. Shoreline survey observations are shown mapped in Figure 14.1.

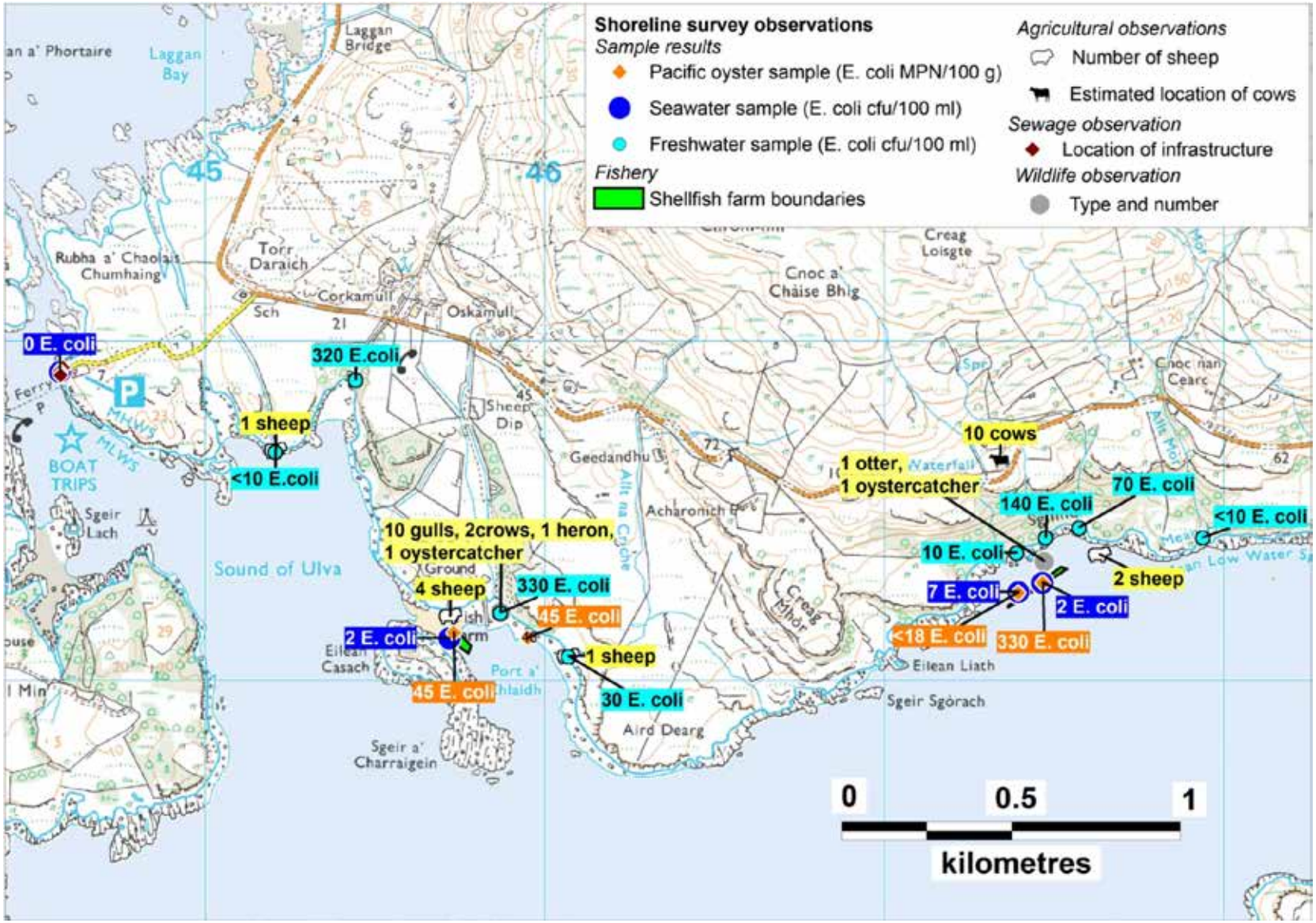


Figure 14.1 Map of shoreline survey observations at Loch na Keal

15. Bacteriological Survey

Both production areas were small and had significant monitoring history with samples taken at a number of locations. No bacteriological survey was undertaken.

16. Overall Assessment

Human sewage impacts

No direct discharges of human sewage were identified to either the Loch na Keal or Loch na Keal West production areas. Two discharges were identified to the Allt na Criche, which flows into Port a' Chlaidh approximately 130 m southeast of the damaged trestles on the eastern shoreline. These were both identified as having secondary treatment, with a combined PE of 15 and the planning consents related to properties at Acharonich and Oskamull which lie over 100 m east and west of the watercourse, respectively. A further four houses were visible in satellite images in the vicinity of Geedandhu. Three of these houses lie adjacent to each other and along the Allt na Criche at Geedandhu. The fourth property lies further to the southwest and is a private home that offers B&B accommodation. Planning records showed three of these as residential dwellings for which applications were received in 2000 and 2001. No information was received on consented discharges associated with these properties, however it is presumed they have private septic tanks that discharge either to Allt na Criche or to soakaway. The water sample from the Allt na Criche returned a relatively low *E. coli* result of 330 cfu/100 ml, suggesting that at the time of survey there unlikely to be significant sewage input to the watercourse.

There appeared to be a significant number of occupied properties in the area for which no discharge consents were available. The majority of these were located away from the shoreline, however several were located near watercourses and therefore may discharge septic tank effluent to these. The majority of these properties were located to the north of the Loch na Keal West production area. Overall, the eastern set of trestles within the Loch na Keal West production area is the most likely to receive any impacts from human sewage.

Agricultural impacts

Areas of improved pasture and land used for grazing are concentrated around the head of the loch and to the north of Port a Chlaidh. The largest concentration of livestock was also seen at the head of the loch, however livestock present along the shore north of the fisheries and along watercourses draining into the production areas would be expected to have the greatest impact on the bacteriological quality of the shellfish. Impacts are likely to be highest at the Loch na Keal West production area, particularly along the eastern shore where pasture lies adjacent to the shoreline. Although there is a farm at Lagganulva, it is not expected to have a significant impact due to its location and distance from the shellfisheries.

At the Loch na Keal production area, the majority of impact from agricultural source diffuse pollution will be carried in watercourses discharging to the production area, mainly along the northeastern boundary. These are likely to have a greater impact at the eastern end of the longline.

Wildlife impacts

Wildlife are expected to contribute to background levels of contamination within the loch and at both fisheries. This will include contamination from seals, seabirds, deer and otters and other small mammals. Any impacts are likely to be greatest at the Loch na Keal West production area, where a larger number of birds may be present on the intertidal area and where watercourses flow into the loch nearer to the farmed shellfish. There is no evidence to suggest that one site will be more impacted than the other within this production area. No spatial variation in wildlife impact is anticipated at the Loch na Keal production area.

Seasonal variation

Seasonal variation is likely in human and livestock populations, with higher numbers expected in both during the summer months. Any effects of this increase are likely to be more apparent at the Loch na Keal West oyster farms, which lie nearer to homes, B&B's and sheep pasture. There is likely to be seasonality to the bird populations in the area, with seabirds likely to be present in higher numbers during the summer breeding season. However, no information was found on seasonal populations of other types of birds in the area.

Analysis of historical *E. coli* monitoring results showed statistically significant seasonal variation, with lowest results seen in spring at both production areas. The effect was more pronounced at Loch na Keal, where results in summer and autumn were found to be significantly higher than in spring. At Loch na Keal West, results in autumn were significantly higher than in spring.

Rivers and streams

Watercourses were found to discharge to both production areas, and these were relatively small in size. Watercourses are expected to carry moderate levels of mainly diffuse-source contamination to both production areas.

Three watercourses with moderate loadings discharge near the Loch na Keal oyster area and these would be expected to potentially impact on the eastern end of the longline. Statistically significant correlations were noted between results and previous two day and seven day rainfall, and a significant negative correlation was found with salinity. These suggest that rainfall-associated runoff is a significant pathway for contamination at this site.

Two watercourses discharge to the Loch na Keal West production area: Allt na Criche and an unnamed watercourse. The unnamed watercourse had the highest calculated loading of those sampled and discharges within 150 m of both trestle areas at Loch na Keal West. Allt na Criche is identified as the receiving water for two consented septic tank discharges, At Loch na Keal West, statistically significant correlations were also noted between results and previous two day and seven day rainfall although no significant correlation was found between results and salinity. It should be noted that the trestle areas are located much closer to the two watercourses than the RMP.

Movement of contaminants

The cumulative transport distance on each phase (flood/ebb) of the tide has been estimated to be around 2 km. Residual flows are relatively weak, indicating that the estuarine circulation is rather weak in this area. Surface contaminants are predicted to be transported primarily along the shoreline. However, the Sound of Ulva is not considered to be a significant pathway for transport of contaminants into or out of Loch na Keal and therefore contamination arising from sources along the Sound of Ulva, such as the public toilets at Ulva Ferry, are unlikely to be transported to the shellfisheries.

No statistically significant associations were found between *E. coli* monitoring results and tidal cycles (high/low and spring/neap) at either production area.

Temporal and geographical patterns of sampling results

E. coli monitoring results at Loch na Keal showed an overall downward trend over the period considered, whilst those at Loch na Keal West appeared to be stable.

There was no clearly discernible geographical pattern in results from either production area, although it was noted at Loch na Keal West that the RMP was not located on the currently active fishery but rather 200 m offshore of it.

No statistically significant difference was found between sampling results taken at Loch na Keal and Loch na Keal West, however due to the differences between sampling location and fishery location, the results from Loch na Keal West may not be representative of conditions at the active fishery.

Conclusions

Overall, both areas appear to be affected by low levels of diffuse faecal contamination. Rainfall runoff is likely to be the principal mechanism through which faecal contaminants are carried to both production areas, as suggested by the statistically significant associations seen between *E. coli* monitoring results and rainfall.

Although no statistically significant difference was found in monitoring results between the two production areas, the Loch na Keal West oyster farms potentially receive greater input from both human and agricultural sources of faecal contamination located nearby. Monitoring at this site has been undertaken at a trestle that no longer forms part of the active fishery and lies further from the identified potential sources of faecal contamination. Therefore, it is not feasible to recommend combining the areas based on the evidence presented here.

17. Recommendations

Loch na Keal

Production area

No changes are recommended to the production area boundaries as identified in the classification document. These are: The area bounded by lines drawn from NM 4700 3908 to NM 4700 3890 and from NM 4800 3890 to NM 4800 3943, extending to MHWS.

RMP

It is recommended that the RMP be relocated to NM 4749 3931, toward the northeast end of the longline area, in order to reflect diffuse contamination carried via watercourses discharging nearer that end of the shellfish farm.

Frequency

Monthly sampling should be continued at this site.

Depth of sampling

The sampling depth should be 4 metres, consistent with the depth at which the culture baskets are hung.

Tolerance

The recommended sampling tolerance at this site is 40 m to allow sufficient scope for locating the sampling point on the longline and to allow for movement of the line on its anchors.

Loch na Keal West

Production area

It is recommended that the production area be curtailed to exclude the eastern shore of Port a Chlaidh as this area is likely to be receive greater impact from faecal contaminants and is not used for harvesting stock. The recommended boundaries are therefore the area bounded by lines drawn from NM 4586 3924 to NM 4600 3880 to NM 4580 3880 to NM 4577 3894 and from NM 4570 3921 to NM 4569 3911, extending to MHWS.

RMP

It is recommended that the RMP be relocated to NM 4569 3911, at the southeastern end of the western trestle area, in order to reflect diffuse contamination arising from land and watercourses along the east shore of Port a Chlaidh and to allow sampling to be undertaken by boat.

Frequency

Monthly sampling should be continued at this site.

Depth of sampling

Not applicable

Tolerance

The recommended sampling tolerance at this site is 20 m to allow sufficient scope for locating a bag on the site.

The recommended production area boundaries and RMPs are shown in Figure 17.1.

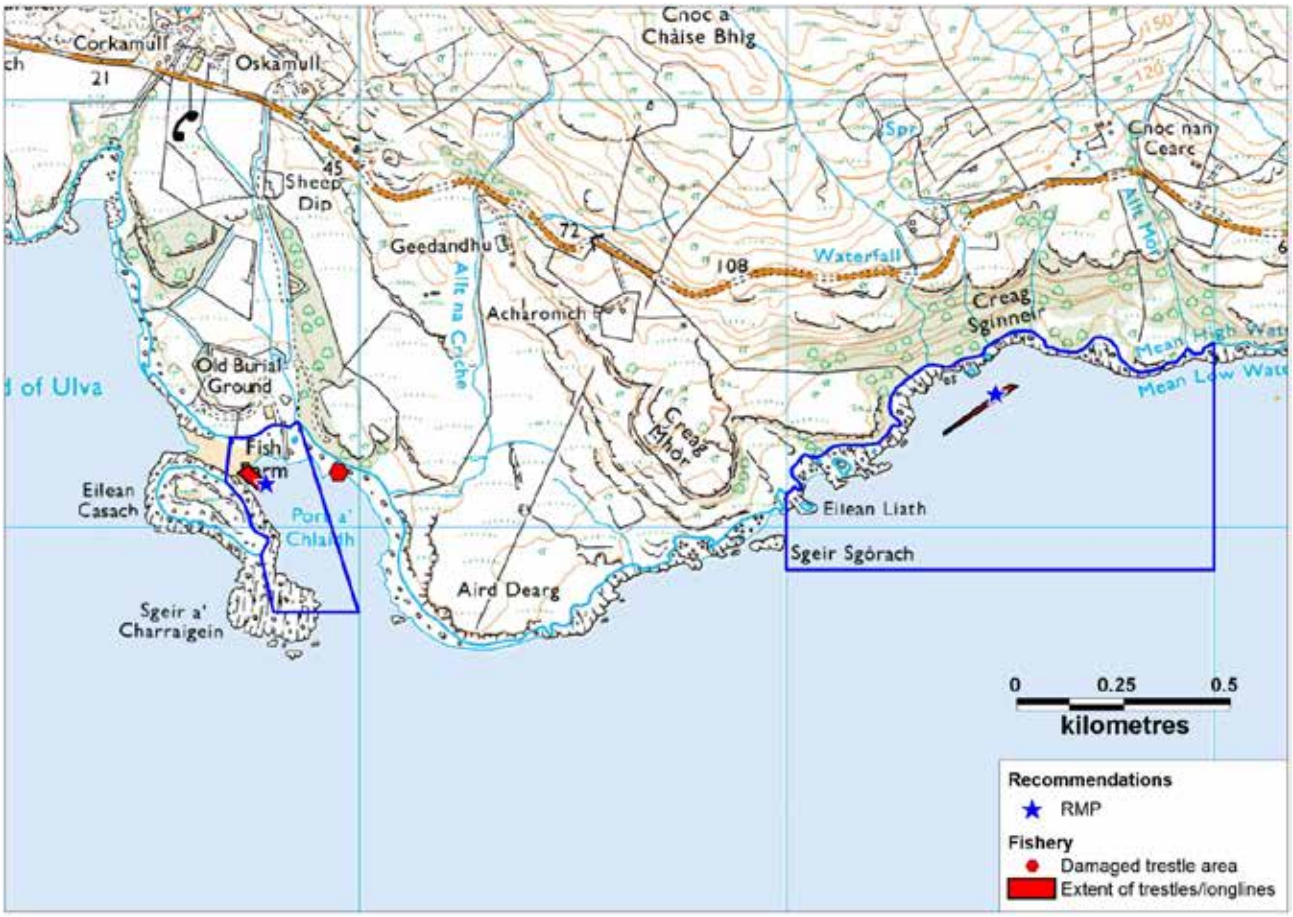


Figure 17.1 Map of recommendations at Loch Na Keal And Loch Na Keal West

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19. List of Figures and Tables

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7. **CTD Data**

1. General Information on Wildlife Impacts

Pinnipeds

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

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

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

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

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

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

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

Cetaceans

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

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

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

Birds

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

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

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

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

Deer

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

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

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

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

Other

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

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

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2. 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

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

comparing base- and high-flow GMs for each group and type.

Source: (Kay, et al., 2008b)

Table 3 – Geometric mean (GM) and 95% confidence intervals (CIs) of the GM faecal indicator organism (FIO) concentrations (cfu/100ml) under base- and high-flow conditions at the 205 sampling points and for various subsets, and results of paired t-tests to establish whether there are significant elevations at high flow compared with base flow

FIO	*n*	**Base Flow**			**High Flow**		
Subcatchment land use		Geometric mean	Lower 95% CI	Upper 95% CI	Geometric mean[a]	Lower 95% CI	Upper 95% CI
Total coliforms							
All subcatchments	205	5.8×10^{3}	4.5×10^{3}	7.4×10^{3}	7.3×10^{4}**	5.9×10^{4}	9.1×10^{4}
Degree of urbanisation							
Urban	20	3.0×10^{4}	1.4×10^{4}	6.4×10^{4}	3.2×10^{5}**	1.7×10^{5}	5.9×10^{5}
Semi-urban	60	1.6×10^{4}	1.1×10^{4}	2.2×10^{4}	1.4×10^{5}**	1.0×10^{5}	2.0×10^{5}
Rural	125	2.8×10^{3}	2.1×10^{3}	3.7×10^{3}	4.2×10^{4}**	3.2×10^{4}	5.4×10^{4}
Rural subcatchments with different dominant land uses							
≥75% Imp pasture	15	6.6×10^{3}	3.7×10^{3}	1.2×10^{4}	1.3×10^{5}**	1.0×10^{5}	1.7×10^{5}
≥75% Rough Grazing	13	1.0×10^{3}	4.8×10^{2}	2.1×10^{3}	1.8×10^{4}**	1.1×10^{4}	3.1×10^{4}
≥75% Woodland	6	5.8×10^{2}	2.2×10^{2}	1.5×10^{3}	6.3×10^{3}*	4.0×10^{3}	9.9×10^{3}
Faecal coliform							
All subcatchments	205	1.8×10^{3}	1.4×10^{3}	2.3×10^{3}	2.8×10^{4}**	2.2×10^{4}	3.4×10^{4}
Degree of urbanisation							
Urban	20	9.7×10^{3}	4.6×10^{3}	2.0×10^{4}	1.0×10^{5}**	5.3×10^{4}	2.0×10^{5}
Semi-urban	60	4.4×10^{3}	3.2×10^{3}	6.1×10^{3}	4.5×10^{4}**	3.2×10^{4}	6.3×10^{4}
Rural	125	8.7×10^{2}	6.3×10^{2}	1.2×10^{3}	1.8×10^{4}**	1.3×10^{4}	2.3×10^{4}
Rural subcatchments with different dominant land uses							
≥75% Imp pasture	15	1.9×10^{3}	1.1×10^{3}	3.2×10^{3}	5.7×10^{4}**	4.1×10^{4}	7.9×10^{4}
≥75% Rough Grazing	13	3.6×10^{2}	1.6×10^{2}	7.8×10^{2}	8.6×10^{3}**	5.0×10^{3}	1.5×10^{4}
≥75% Woodland	6	3.7×10	1.2×10	1.2×10^{2}	1.5×10^{3}**	6.3×10^{2}	3.4×10^{3}
Enterococci							
All subcatchments	205	2.7×10^{2}	2.2×10^{2}	3.3×10^{2}	5.5×10^{3}**	4.4×10^{3}	6.8×10^{3}
Degree of urbanisation							
Urban	20	1.4×10^{3}	9.1×10^{2}	2.1×10^{3}	2.1×10^{4}**	1.3×10^{4}	3.3×10^{4}
Semi-urban	60	5.5×10^{2}	4.1×10^{2}	7.3×10^{2}	1.0×10^{4}**	7.6×10^{3}	1.4×10^{4}
Rural	125	1.5×10^{2}	1.1×10^{2}	1.9×10^{2}	3.3×10^{3}**	2.4×10^{3}	4.3×10^{3}
Rural subcatchments with different dominant land uses							
≥75% Imp. pasture	15	2.2×10^{2}	1.4×10^{2}	3.5×10^{2}	1.0×10^{4}**	7.9×10^{3}	1.4×10^{4}
≥75% Rough Grazing	13	4.7×10	1.7×10	1.3×10^{2}	1.2×10^{3}**	5.8×10^{2}	2.7×10^{3}
≥75% Woodland	6	1.6×10	7.4	3.5×10	1.7×10^{2}**	5.5×10	5.2×10^{2}
[a] Significant elevations in concentrations at high flow are indicated: **po0.001, *po0.05.							
[b] Degree of urbanisation categorised according to percentage built-up land: 'Urban' (X10.0%), 'Semi-urban' (2.5–9.9%) and 'Rural' (o2.5%).							

Source: (Kay, et al., 2008a)

Table 4 - 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: (Gauthier & Bedard, 1986)

References

Gauthier, G. & Bedard, J., 1986. Assessment of faecal output in geese. *Journal of Applied Ecology,* 23(1), pp. 77-90.

Kay, D. et al., 2008a. Faecal indicator organism concentrations and catchment export coefficients in the UK. *Water Research,* 42(10/11), pp. 2649-2661.

Kay, D. et al., 2008b. Faecal indicator organism in concentration sewage and treated effluents. *Water Research,* 42(1/2), pp. 442-454.

3. Statistical Data

One-way ANOVA: logec versus Season Loch na Keal

Source DF SS MS F P
Season 3 3.163 1.054 4.32 0.008
Error 63 15.365 0.244
Total 66 18.528

S = 0.4939 R-Sq = 17.07% R-Sq(adj) = 13.12%

Individual 95% CIs For Mean Based on Pooled StDev

```
Level   N    Mean   StDev  --+---------+---------+---------+-------
1      17  1.0851  0.2197  (-------*-------)
2      18  1.5463  0.6481               (-------*------)
3      16  1.6317  0.6355                 (-------*--------)
4      16  1.2755  0.3048        (--------*-------)
                   --+---------+---------+---------+-------
                   0.90      1.20      1.50      1.80
```

Pooled StDev = 0.4939

Grouping Information Using Tukey Method

Season N Mean Grouping
3 16 1.6317 A
2 18 1.5463 A
4 16 1.2755 A B
1 17 1.0851 B

Means that do not share a letter are significantly different.

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       0.0207  0.4612  0.9017               (--------*--------)
3       0.0929  0.5466  1.0003                 (--------*--------)
4      -0.2633  0.1904  0.6441           (--------*--------)
                       -------+---------+---------+---------+---
                         -0.50      0.00      0.50      1.00
```

Season = 2 subtracted from:

```
Season   Lower   Center  Upper  -------+---------+---------+---------+---
3      -0.3622   0.0854  0.5329          (--------*--------)
4      -0.7184  -0.2708  0.1767    (--------*--------)
                       -------+---------+---------+---------+---
                         -0.50      0.00      0.50      1.00
```

Season = 3 subtracted from:

```
Season   Lower   Center  Upper  -------+---------+---------+---------+---
4      -0.8167  -0.3562  0.1043  (--------*--------)
```

```
                      ------+---------+---------+---------+---
                        -0.50      0.00      0.50      1.00
```

One-way ANOVA: logec versus Season Loch na Keal West

Source	DF	SS	MS	F	P
Season	3	2.464	0.821	4.06	0.011
Error	64	12.946	0.202		
Total	67	15.410			

S = 0.4498 R-Sq = 15.99% R-Sq(adj) = 12.05%

```
                      Individual 95% CIs For Mean Based on
                      Pooled StDev
Level   N    Mean   StDev ------+---------+---------+---------+---
1      17  1.0708  0.1316  (--------*--------)
2      18  1.3424  0.4545           (--------*-------)
3      16  1.6174  0.6520                    (--------*--------)
4      17  1.3309  0.4169           (-------*--------)
                    ------+---------+---------+---------+---
                       1.00      1.25      1.50      1.75
```

Pooled StDev = 0.4498

Grouping Information Using Tukey Method

Season	N	Mean	Grouping
3	16	1.6174	A
2	18	1.3424	A B
4	17	1.3309	A B
1	17	1.0708	B

Means that do not share a letter are significantly different.
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	-0.1296	0.2716	0.6728
3	0.1334	0.5466	0.9598
4	-0.1468	0.2601	0.6670

```
                      ----+---------+---------+---------+-----
                       -0.50      0.00      0.50      1.00
```

Season = 2 subtracted from:

Season	Lower	Center	Upper
3	-0.1325	0.2750	0.6826
4	-0.4127	-0.0115	0.3897

```
                      ----+---------+---------+---------+-----
                       -0.50      0.00      0.50      1.00
```

Season = 3 subtracted from:

Season	Lower	Center	Upper
4	-0.6997	-0.2865	0.1267

```
                      ----+---------+---------+---------+-----
                       -0.50      0.00      0.50      1.00
```

4. Hydrographic Assessment Glossary

The following technical terms may appear in the hydrographic assessment.

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

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

MHW. Mean High Water, The highest level that tides reach on average.

MHWN. Mean High Water Neap, The highest level that tides reach on average during neap tides.

MHWS. Mean High Water Spring, The highest level that tides reach on average during spring tides

MLW. Mean Low Water, The lowest level that tides reach on average.

MLWN. Mean Low Water Neap, The lowest level that tides reach on average during neap tides.

MLWS. Mean Low Water Spring, The lowest level that tides reach on average during spring tides.

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

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

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

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

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

Spring/Neap Tides. Spring tides occur during or just after new moon and full moon when the tide-generating force of the sun acts in the same direction as that of the moon, reinforcing it. The tidal range is greatest and tidal currents strongest during spring tides.

Neap tides occur during the first or last quarter of the moon when the tide-generating forces of the sun and moon oppose each other. The tidal range is smallest and tidal currents are weakest during neap tides.

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

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

Return flow. A surface flow at the surface may be accompanied by a compensating flow in the opposite direction at the bed.

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

5. Shoreline Survey Report

Report Title	Loch na Keal Shoreline Survey Report
Project Name	Shellfish Sanitary Surveys
Client/Customer	Cefas
SRSL Project Reference	00561_B0067

Document Number	B0067_Shoreline 0027

Revision History

Revision	Changes	Date
A	Issue for internal review	05/02/2014
B	Issue incorporating corrections from previous version	06/02/2014
C	Corrections completed	18/02/2014
01	First formal issue to client	20/02/2014
02	Second formal issue incorporating comments from client in issue 01 and from harvester	17/03/2014

	Name & Position	Date
Author	Lars Brunner Gail Twigg	05/02/2014
Checked	Andrea Veszelovszki	17/03/2014
Approved	Andrea Veszelovszki	17/03/2014

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Shoreline Survey Report

Production area:	Loch na Keal
	Loch na Keal West
Site name:	Eilean Liath
	Eilean Casach
SIN:	AB-284-080-13 (Eilean Liath)
	AB-286-082-13 (Eilean Casach)
Species:	Pacific Oyster (*Crassostrea gigas*)
Harvester:	Mr Nick Mawhinney
Local Authority:	Argyll & Bute
Status:	Existing area
Date Surveyed:	28th & 29th January 2014
Surveyed by:	Lars Brunner, Gail Twigg
Existing RMP:	NM 4742 3929 (Eilean Liath)
	NM 5484 3891 (Eilean Casach)

Area Surveyed:

Section 1: Eilean Liath (Loch na Keal) production area and its adjacent shoreline area started at the most easterly point, as marked on the shoreline survey plan, continuing westward for approximately 0.5km.

Section 2: Eilean Casach (Loch na Keal West) production area and the shoreline starting on the east side of Port a' Chlaidh running westward for approximately 1.5km.

Section 3: A short section of approximately 100m at Ulva Ferry slipway.

Weather

There was persistent heavy rainfall for the 48 hours leading up to the survey and the area was also subject to severe storms in recent months prior to that.

28th January: wind E/SE F 2-3; cloud cover approximately 30%; temperature 4°C; sea state: small wavelets. Weather cold but sunny with light cloud.

29th January: wind S/SE F 3-4; cloud cover approximately 65%; temperature 6°C; sea state small waves. Weather dry but with thickening cloud.

Stakeholder engagement during the survey

The harvester Mr Nick Mawhinney was contacted prior to the survey and he offered advice and assistance during preparation for the survey. Mr Mawhinney and his son Mr Dan Mawhinney were extremely helpful during the survey by providing access to some of the more inaccessible areas of the survey route with the use of their boat. In addition, both Mr Mawhinney and his son provided much information about the current state, and future plans for the site.

Contact was made prior to the survey with Allison Hardie, the local authority sampling officer, and she also provided information regarding the current state of the fishery, as well as general information on access to the site. It was not possible for her to be present during the survey, due to other commitments.

Fishery

The stakeholder, Mr Mawhinney, owns three different seabed leases in the area. Two seabed leases are situated at the Eilean Casach production area within Port a' Chlaidh, one is adjacent to the sound of Ulva on the west and the other is located on the east shore of the bay. The eastern shore site was small containing only five oyster trestles, only three of which had bags attached. The harvester stated that the trestles had been damaged by winter storms and some bags had been lost.

The Eilean Liath production area lies approximately 1 km further east, within Loch na Keal. Both sites, Eilean Liath and Eilean Casach, are currently being used for the cultivation of Pacific Oysters (Crassostrea gigas). At the Eilean Casach site the oysters are grown on intertidal trestles (Figure 13). There were around 200 trestles with 8 bags on each with oyster sizes ranging from between 30 – 100 mm. The bags were attached using bungees and turned regularly.

At the Eilean Liath site the fishery is one of suspended culture with oysters grown in baskets hanging between 2-4m depth from a long line (Figure 3). At the time of survey there was only one long line in use. The second line is not in use as it was damaged in recent storms, but the surveyors were informed by the harvester's son Mr Dan Mawhinney that this will be restored and a third line is also planned to be set up in the future. Oysters here were a mixture of young and old, but mostly young.

Mr Mawhinney sells on to other producers and at present no depuration is carried out on site. Mr Mawhinney stated that he was looking to expand the business and increase production and at present is in discussion with Marine Scotland, The Crown Estate and Argyll & Bute Council.

Access to production site

Allison Hardie, the sampling officer for the area, advised us prior to survey that she expected much of the shoreline identified in the survey plan to be inaccessible and as predicted access to some areas of the fisheries was indeed challenging.

The Loch na Keal area of Mull consists of very rough ground, steep rocky slopes covered with native woodland and rough moorland down to the loch side making parts of the shoreline inaccessible from the nearest road some 200m away. In addition to this, some parts of the survey route were too steep and rocky to walk with safety. Indeed, if it were not for the enormous help from the harvester, Mr Nick Mawhinney and his son Mr Dan Mawhinney, and the use of their boat, then large areas of the route could not have been surveyed.

This is particularly true of the deep water Eilean Liath site where gaining access from the road or from along the shore was deemed unsafe. Not only did the harvester's son Mr Dan Mawhinney assist the survey team by taking them out on the boat to sample seawater and shellfish, check the RMP position and extent of the fish farm, but also dropped the survey team on the shore at the furthest easterly point of the shoreline walk at Eilean Liath (waypoint 13/14) and collected them at the western end, after finishing the shoreline part of the survey (waypoint 19/20). Mr Dan Mawhinney kept the boat close to shore should the surveyors require any assistance.

Similarly, parts of Eilean Casach were also inaccessible. Again Mr Dan Mawhinney was able to assist by putting the survey team on shore at the western end of the shoreline walk at waypoints 30 and 32. The shore between these points was too steep to walk. Because the weather was calm Mr Dan Mawhinney was able to get in close so the surveyors could get a good look at the shore. Mr Dan Mawhinney also used the boat so the surveyors could confirm the location of the RMP and southern corners of the Eilean Casach production site.

Sewage Sources

The shoreline around the survey area is sparsely inhabited, with isolated houses and farms set back from the shoreline, with some storage sheds located at Ulva Ferry. There are public toilets situated at the ferry slipway at Ulva Ferry, with two discharge pipes running to holding chambers/septic tanks, and from there, down the shoreline into the loch (Figure 10, 11). One of the pipes ended in a redundant pump chamber which was previously used to flush toilets (information from harvester) (Figure 12). The end of the other discharge pipe was too far out in the loch to see any similar submerged chamber. The harvester, Mr Mawhinney, noted that there is a strong seasonal usage of the public toilet facilities at the ferry. Other than these pipes from the public toilets, no other discharge pipes were noted on the survey route. The plastic pipe noted on the shore in front of the fish farm at Eilean Casach was a

pump intake pipe for shellfish washing, rather than output pipe (information acquired from harvester) (Figure 8).

Seasonal Population

No campsites, caravan parks, hotels or B&Bs were noted in the survey area. As the properties around the survey area were much dispersed, it was difficult to determine whether or not holiday homes were in the area, although some may be present. Ulva Ferry is the launching point for cruises to Staffa and the Treshnish Isles during the summer, therefore it is likely that there are an increased number of people passing through during these months.

Boats/Shipping

There were no piers or slipways in the Eilean Liath production area. Eilean Casach production area possessed two slipways and a floating pontoon (Figure 7) used by the fish farm base, and a small natural slipway (Figure 6) used by the harvester Mr Mawhinney. Ulva Ferry also had a small combined pier and slipway.

There were no moorings or boats noted in the Eilean Liath production area. Eilean Casach had two fixed moorings in the bay at Port a' Chlaidh. The Sound of Ulva around Ulva ferry possessed around twenty moorings with a mixture of small dinghies and two small fishing boats.

Farming and Livestock

Very little livestock was observed on the survey route, with only two sheep being seen in the Eilean Liath production area, and another six in total seen in the Eilean Casach production area (Table 1). Farms were present in the area around the survey, and around ten cows were seen in a field by the roadside above Eilean Liath. The team had been advised by the harvester, Mr Mawhinney, that sheep had been present in the fields adjacent to the survey route in Eilean Casach, but had been moved to a holding field nearer the main road a few days prior to the survey.

Land Use

Land use around the survey area is rural, with the hillsides above the survey area being a mixture of heath, moor and native woodland, with some grazed ground. The lower areas to the south and west of the main road are grazed fields with areas of native woodland and bog also present. Housing is sparse, with a very low population density. There are a small collection of sheds at Ulva Ferry, but their purpose is unknown.

Land Cover

The Eilean Liath survey area consisted of very rough ground, with steep rocky slopes covered with native woodland and rough moorland down to the

shoreline (Figure 4). Eilean Casach was a mix of improved grazed field with bog, small areas of native woodland and moor present.

Watercourses

All of the watercourses encountered on the survey were small streams of largely similar size (Figure 9). The largest was probably Allt na Criche running into Port a' Chlaidh on the eastern shore (waypoints 21/22, LNKFW5). There were many areas of natural seepage (Figure 5).

It was noted during this part of the shoreline survey that the watercourse (NM4733 3938) indicated on the survey plan was not as shown on the map but situated to the east of that point (waypoint 20).

Wildlife/Birds

Comparatively little wildlife was observed during the survey. One otter was seen in the Eilean Liath survey area and one oyster catcher. In the Eilean Casach area ten gulls, two crows, one heron and an oyster catcher were observed.

Shoreline Survey Maps

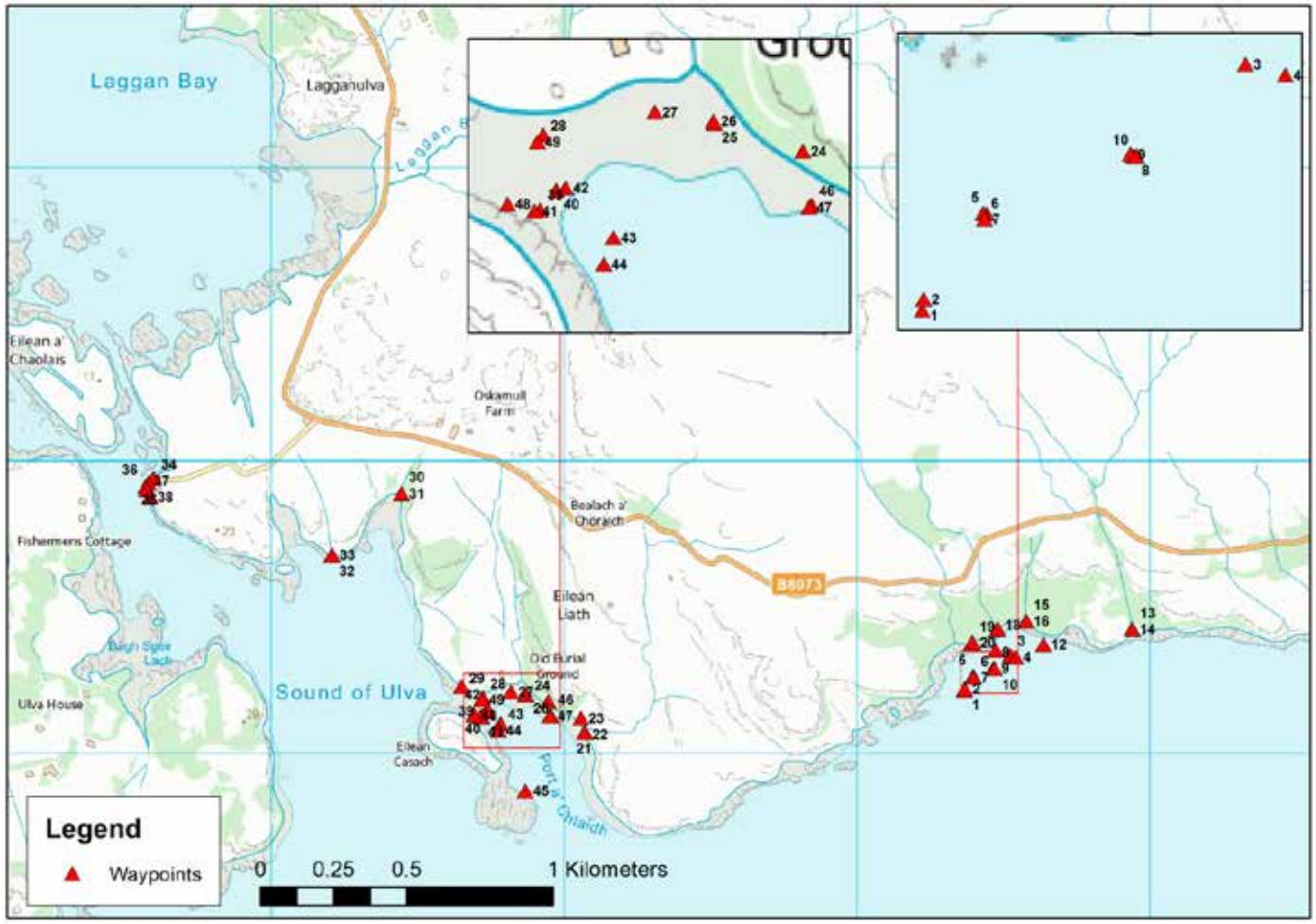

Figure 1: Loch na Keal waypoints

Figure 2: Loch na Keal samples

Table 1: Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
1	28/01/2014	9:31	NM 47366 39215	147366	739215			South western corner of oyster farm at deep water site at Eilean Liath. Surveyed using harvester's boat.
2	28/01/2014	9:31	NM 47367 39220	147367	739221			North western corner of oyster farm at deep water site at Eilean Liath. Surveyed using harvester's boat.
3	28/01/2014	9:33	NM 47522 39334	147522	739334	Fig. 3		North eastern corner of oyster farm at deep water site at Eilean Liath. Surveyed using harvester's boat.
4	28/01/2014	9:33	NM 47541 39328	147541	739329			South eastern corner of oyster farm at deep water site at Eilean Liath. Surveyed using harvester's boat.
5	28/01/2014	9:41	NM 47397 39262	147397	739262		LNKSW1	Planned seawater sample 1.
6	28/01/2014	9:44	NM 47395 39262	147396	739262			RMP monitoring point. CTD cast.
7	28/01/2014	9:46	NM 47396 39259	147396	739260		LNKSF1	Oysters cultivated in baskets suspended from a long line. Oysters sampled from western end of line.
8	28/01/2014	9:53	NM 47468 39289	147468	739290		LNKSW2	Planned seawater sample 2.
9	28/01/2014	9:55	NM 47466 39290	147467	739291			CTD cast at eastern end of long line.
10	28/01/2014	9:55	NM 47469 39289	147470	739290		LNKSF2	Oysters sampled from eastern end of line.
11	28/01/2014	10:06	NM 47473 39351	147473	739352			Young otter in water near to shore. One oyster catcher on shore.
12	28/01/2014	10:08	NM 47636 39371	147636	739372			Two sheep up on rocks. Waypoint taken from boat.
13	28/01/2014	10:15	NM 47941 39422	147941	739423		LNKFW1	Planned freshwater sample.
14	28/01/2014	10:15	NM 47939 39424	147940	739424			Observations associated with sample from

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
								waypoint 13. Width 1.2 m; Depth 15 cm; Flow 0.686 m/s; S.D. 0.020. Stream flowing through rough grassland, continuing over rocky shore to the loch.
15	28/01/2014	10:32	NM 47576 39451	147577	739452		LNKFW2	Planned freshwater sample 2.
16	28/01/2014	10:32	NM 47576 39452	147577	739452	Fig. 4		Observations associated with sample from waypoint 15. Width 55 cm; Depth 10 cm; Flow 0.663 m/s; S.D. 0.018. Stream spilt into two flows lower down over the shore, reading taken above the shore. Some debris on shore.
17	28/01/2014	10:42	NM 47478 39422	147478	739423		LNKFW3	Planned freshwater sample 3.
18	28/01/2014	10:42	NM 47479 39426	147479	739426			Observations associated with sample from waypoint 17. Width 1.0 m; Depth 15 cm; Flow 0.325 m/s; S.D. 0.018. Stream running through rough wood and bush land, over large boulders and rocky shore to the loch.
19	28/01/2014	10:56	NM 47392 39377	147392	739377		LNKFW4	Planned freshwater sample 4.
20	28/01/2014	10:56	NM 47393 39378	147394	739378			Observations associated with sample from waypoint 19. Watercourse (NM4733 3938) not as indicated on the map but found situated to the east of that point. The watercourse spilt in two as follows: (1) Width 20 cm; Depth 5 cm; Flow 0.745 m/s; S.D. 0.023 (2) Width 35cm; Depth 7 cm; Flow 0.463 m/s; S.D.0.009.
21	28/01/2014	11:18	NM 46071 39072	146071	739073		LNKFW5	Planned freshwater sample 5.
22	28/01/2014	11:19	NM 46071 39072	146071	739073			Observations associated with sample from waypoint 21. Width 1.20 m; Depth 13 cm; Flow 0.507 m/s; S.D. 0.026. Stream running through rough grassland, over large boulders and rocky

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
								shore to the loch. One sheep noted in field above the stream.
23	28/01/2014	11:24	NM 46056 39120	146057	739120	Fig. 5		Ground water coming from bog. Not sampled as same source as waypoint 22 stream. Debris present.
24	28/01/2014	11:30	NM 45946 39176	145947	739177	Fig. 6		Natural slipway on shore. No discharge pipe present. Two buoys and 2 moorings in the bay.
25	28/01/2014	11:35	NM 45870 39200	145870	739200		LNKFW6	Planned freshwater sample 6.
26	28/01/2014	11:35	NM 45869 39202	145870	739203			Observations associated with sample from waypoint 25. Width 1.10 m; Depth 13 cm; Flow 0.328m/s; 0.003. Stream situated east of the fish farm base, running down algae covered shore. Ten gulls, two crows, one heron and one oyster catcher visible.
27	28/01/2014	11:41	NM 45818 39210	145819	739210	Fig. 7		Fish farm pontoon with access road at top of the shore. No discharge pipes noted.
28	28/01/2014	11:47	NM 45722 39190	145722	739191	Fig. 8		Rough slipway on shore. Shed building above shore next to fish farm building. Four sheep noted at shed area. Two oyster trestles on the shore. A 6 cm dia. plastic pipe running from intake box on the shore up towards shed. Intake rather than output, no discharge noted.
29	28/01/2014	11:52	NM 45650 39228	145650	739229			Storage area for fish farm equipment at top of the shore.
30	28/01/2014	12:07	NM 45444 39886	145445	739886		LNKFW7	Planned freshwater sample 7.
31	28/01/2014	12:07	NM 45444 39887	145445	739888	Fig. 9		Observations associated with sample from waypoint 30. Width 50 cm; Depth 9 cm; Flow 0.662 m/s; S.D. 0.015. Large amount of algae and debris backed up on the shore line.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
32	28/01/2014	12:22	NM 45206 39675	145206	739675		LNKFW8	Planned freshwater sample 8.
33	28/01/2014	12:22	NM 45207 39678	145207	739678			Observations associated with sample from waypoint 32. Width 25 cm; Depth 20 cm; Flow 0.068 m/s; S.D. 0.011. One sheep noted at top of the shore.
34	28/01/2014	13:22	NM 44597 39939	144598	739939			Start of shore walk at Ulva Ferry. Inner bay six small craft moored plus seven empty moorings. Outer bay seven moorings, two of which occupied with small fishing boats.
35	28/01/2014	13:25	NM 44579 39922	144580	739923	Figs. 10 & 11		10 cm metal pipe running from toilet block to loch. End of discharge pipe under water at time of survey therefore any discharge present not detectably. One male, one female toilet.
36	28/01/2014	13:28	NM 44572 39911	144572	739912		LNKSW3	Planned seawater sample 3.
37	28/01/2014	13:29	NM 44574 39901	144574	739901	Fig. 12		10 cm metal pipe running from toilet block to loch. Discharge pipe ends in submerged chamber therefore any discharge present not detectable.
38	28/01/2014	13:32	NM 44586 39875	144587	739876			Ulva Ferry slipway. Sheds and storage area at top of the shore for oil tanks, fishing gear, creels.
39	29/01/2014	9:24	NM 45719 39126	145720	739126		LNKSW4	Planned seawater sample 4.
40	29/01/2014	9:41	NM 45733 39142	145734	739143		LNKSF3	Planned shellfish sample 3.
41	29/01/2014	9:48	NM 45714 39124	145715	739125			North western corner of oyster trestles at Eilean Casach.
42	29/01/2014	9:48	NM 45741 39144	145742	739145	Fig. 13		North eastern corner of oyster trestles at Eilean Casach.
43	29/01/2014	10:12	NM 45783 39101	145783	739102			South eastern corner of oyster trestles at Eilean Casach.
44	29/01/2014	10:13	NM 45775 39078	145775	739079			South western corner of oyster trestles at Eilean Casach.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
45	29/01/2014	10:13	NM 45793 39056	145794	739056			RMP monitoring point.
46	29/01/2014	10:17	NM 45954 39130	145954	739130			Five oyster trestles, three with bags. Harvester stated that trestles damaged by winter storms, some bags lost.
47	29/01/2014	10:18	NM 45952 39128	145952	739128		LNKSF4	Unplanned shellfish sample associated with waypoint 46. Extra sample.
48	29/01/2014	10:29	NM 45691 39130	145692	739131			Separate from main trestles. Old section of a pontoon with 18 oyster bags.
49	29/01/2014	10:31	NM 45717 39184	145718	739184			Separate from main trestles. Old section of a pontoon with 15 oyster bags.

Photographs referenced in the table can be found attached as Figures 3 – 13.

Sampling

Water samples were collected at the sites marked on the Loch na Keal sample map shown in Figure 2. All the samples were transferred to Biotherm 10 boxes along with ice packs and posted to the Glasgow Scientific Services (GSS) for E. coli analysis. Due to the site location, a 48 hour extension had been granted prior to survey. Some samples were posted the day after collection and some on the day of collection. All samples were received within the 48 hours extension agreed. The sample temperatures on arrival at the laboratory were recorded between 2.3 and 3.1 °C.

Seawater samples were tested for salinity by GSS and the results were reported in mg Chloride per litre. These results have been converted to parts per thousand (ppt) using the formula:

$$\text{Salinity (ppt)} = 0.0018066 \times Cl \ \text{(mg/L)}$$

Shellfish samples were collected from both production areas. The harvester's boat was used at the deep water, Eilean Liath site while the surveyors were able to access some of the intertidal trestles at low tide at the Eilean Casach production area.

LNKSF4 (waypoint 47) was an extra shellfish sample taken from the second seabed lease area on the east shore at Eilean Casach.

Table 2. Water Sample Results

No.	Date	Sample	Grid Ref	Type	*20. E. coli* (cfu/100ml)	Salinity (ppt)
1	28/01/2014	LNKSW1	NM 47397 39262	Seawater	7	31.98
2	28/01/2014	LNKSW2	NM 47468 39289	Seawater	2	31.98
3	28/01/2014	LNKFW1	NM 47941 39422	Freshwater	<10	-
4	28/01/2014	LNKFW2	NM 47576 39451	Freshwater	70	-
5	28/01/2014	LNKFW3	NM 47478 39422	Freshwater	140	-
6	28/01/2014	LNKFW4	NM 47392 39377	Freshwater	10	-
7	28/01/2014	LNKFW5	NM 46071 39072	Freshwater	30	-
8	28/01/2014	LNKFW6	NM 45870 39200	Freshwater	330	-
9	28/01/2014	LNKFW7	NM 45444 39886	Freshwater	320	-
10	28/01/2014	LNKFW8	NM 45206 39675	Freshwater	<10	-
11	28/01/2014	LNKSW3	NM 44572 39911	Seawater	0	33.06
12	29/01/2014	LNKSW4	NM 45719 39126	Seawater	2	30.35

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	21. Sample depths	*22. E. coli* (MPN/100g)
1	28/01/2014	LNKSF1	NM 47396 39259	Pacific oyster	~ 4 m	<18
2	28/01/2014	LNKSF2	NM 47469 39289	Pacific oyster	~ 4 m	330
3	29/01/2014	LNKSF3	NM 45733 39142	Pacific oyster	-	45

No.	Date	Sample	Grid Ref	Type	21. Sample depths	22. *E. coli* (MPN/100g)
4	29/01/2014	LNKSF4	NM 45952 39128	Pacific oyster	-	45

Salinity Profiles

Salinity profiles were taken using the harvester's boat at two locations at the Eilean Liath production area, one at each end of the long line with suspended baskets (waypoints 6 and 9).

Photographs

Figure 3: Long line with suspended oyster baskets at Eilean Liath (Waypoint 4)

Figure 4: Fresh water stream at Eilean Liath, location of water sample LNKFW2 (Waypoint 16)

Figure 5: Ground water from bog and scattered debris at Eilean Casach (Waypoint 23)

Figure 6: Natural slipway on shore at Eilean Casach (Waypoint 24)

Figure 7: Floating pontoon at Eilean Casach fish farm (Waypoint 27)

Figure 8: Plastic pipe and intake box on shore at Eilean Casach fish farm (Waypoint 28)

Figure 9: Large amount of algae and debris backed up on shore in bay in Sound of Ulva. Water sample LNKFW7 (Waypoint 31)

Figure 10: Discharge pipe running from public toilet block into loch at Ulva Ferry (Waypoint 35)

Figure 11: Public toilet block and discharge pipe at Ulva Ferry (Waypoint 35)

Figure 12: Discharge pipe running into submerged chamber (Waypoint 37)

Figure 13: Oyster trestles at Eilean Casach (Waypoint 42)

6. Discharge Consents – SEPA

Licence No.	NGR	Site Name	Discharge Type	Discharges to	PE
CAR/R/1040278	NM 45824 40111	Private Dwelling, Ulva Ferry, Isle of Mull	Septic tank	Soakaway	6
CAR/R/1041565	NM 46060 39860	Private Dwelling,Oskamull, Isle Of Mull	Septic Tank	Soakaway	6
CAR/R/1037758	NM 46110 39940	Private Dwelling, Ulva Ferry, Isle of Mull	Sewage (Private) Primary	Soakaway	5
CAR/R/1096123	NM 46278 39649	Private Dwelling, Ulva Ferry, Isle of Mull	Sewage (Private) Secondary	Allt na Criche	10
CAR/R/1080612	NM 46284 39781	Private Dwelling, Ulva Ferry, Isle of Mull	STW	Allt Na Criche	6
CAR/R/1011866	NM 49634 35700	Private Dwelling -Isle of Mull	Sewage (Private) Primary	U/N W/C	10
CAR/R/1100539	NM 50500 40140	Private Dwelling, Isle of Mull	Sewage (Private) Primary	Soakaway	10
CAR/R/1038680	NM 51948 40611	Private Dwelling, Aros, Isle of Mull	Sewage (Private) Primary	Soakaway	5
CAR/R/1040739	NM 53075 41549	Private Dwelling, Killiechronan, Isle of Mull	Septic Tank	soakaway	5
CAR/R/1039621	NM 53843 41265	Private Dwelling, Killiechronan,Isle of Mull	Sewage (Private) Primary	Soakaway	50
CAR/R/1039633	NM 53937 41289	Private Dwelling, Killiechronan, Ise of Mull	Septic tank	Soakaway	30
CAR/R/1039628	NM 54100 41270	Private Dwelling, Killiechronan, Isle of Mull	Sewage (Private) Primary	Soakaway	50
CAR/R/1039625	NM 54102 41268	Private Dwelling, Killiechronan, Isle of Mull	Sewage (Private) Primary	Soakaway	50
CAR/R/1039638	NM 54110 41260	Private Dwelling	Sewage (Private) Primary	Soakaway	50
CAR/R/1039824	NM 54246 41319	Private Dwelling, Killiechronan, Isle of Mull	Sewage (Private) Primary	Soakaway	50
CAR/R/1039636	NM 54250 41300	Private Dwelling, Killiechronan, Isle of Mull	Sewage (Private) Primary	Soakaway	50
CAR/R/1038228	NM 54300 40050	Private Dwelling, Gruline	Sewage (Private) Primary	Soakaway	8
CAR/R/1081961	NM 54353 40567	Private Dwelling, Gruline, Mull	Sewage (Private) Primary	Soakaway	15
CAR/R/1077277	NM 54376 38944	Private Dwelling, Gruline, Isle of Mull	Septic tank	Soakaway	12
CAR/R/1077288	NM 54430 40070	Private Dwelling, Gruline, Isle of Mull	Sewage (Private) Primary	Soakaway	5
CAR/R/1077284	NM 54480 38881	Private Dwelling, Gruline, Isle of Mull	Septic tank	Soakaway	6
CAR/R/1099669	NM 54560 40560	Private Dwelling, Gruline, Isle of Mull	Septic Tank	Soakaway	6
CAR/R/1076757	NM 54585 38834	Private Dwelling, Gruline, Isle of Mull	Septic tank	Soakaway	5
CAR/R/1080185	NM 54600 38886	Private Dwelling, Gruline, Isle of Mull	Septic Tank	Soakaway	5
CAR/R/1076764	NM 54630 38839	Private Dwelling, Gruline, Isle of Mull	Septic Tank	Soakaway	5
CAR/R/1076751	NM 54667 38952	Private Dwelling, Gruline, Mull	Septic tank	Soakaway	10

Licence No.	NGR	Site Name	Discharge Type	Discharges to	PE
CAR/R/1077306	NM 54700 39918	Private Dwelling, Gruline, Isle of Mull	Sewage (Private) Primary	Soakaway	5
CAR/S/1009629	NM 54720 38920	Private Dwelling, Gruline, Mull	Secondary Treatment	River Ba	20
CAR/R/1037540	NM 54810 39980	Private Dwelling	Sewage (Private) Primary	Soakaway	24
CAR/R/1037541	NM 54820 39980	Private Dwelling	Sewage (Private) Primary	Soakaway	6
CAR/R/1040009	NM 55150 39230	Private Dwelling, Isle of Mull	Sewage (Private) Primary	Loch Ba	11
CAR/R/1014207	NM 55181 39354	Private Dwelling, Gruline, Isle of Mull	Septic tank	Loch Ba	6
CAR/R/1039995	NM 55290 39354	Private Dwelling, Gruline Isle of Mull	Septic tank	Soakaway	5
CAR/R/1040020	NM 55316 39369	Private Dwelling, Isle of Mull	Septic tank	Soakaway	7
CAR/R/1020557	NM 55510 40810	Proposed Dwelling (plot 1), Torlochan, Mull	stw	soakaway	5
CAR/R/1020560	NM 55520 40730	Proposed Dwelling (Plot 2), Torlochan, Mull	STW	land	5
CAR/R/1036264	NM 53062 41463	Private Dwelling, Aros, Mull	Sewage (Private) Primary	U/T of River Ba estuary	6

Appendix 7. Loch na Keal CTD data

Data obtained during the shoreline survey. The locations of the casts are shown in Figure A7.1.

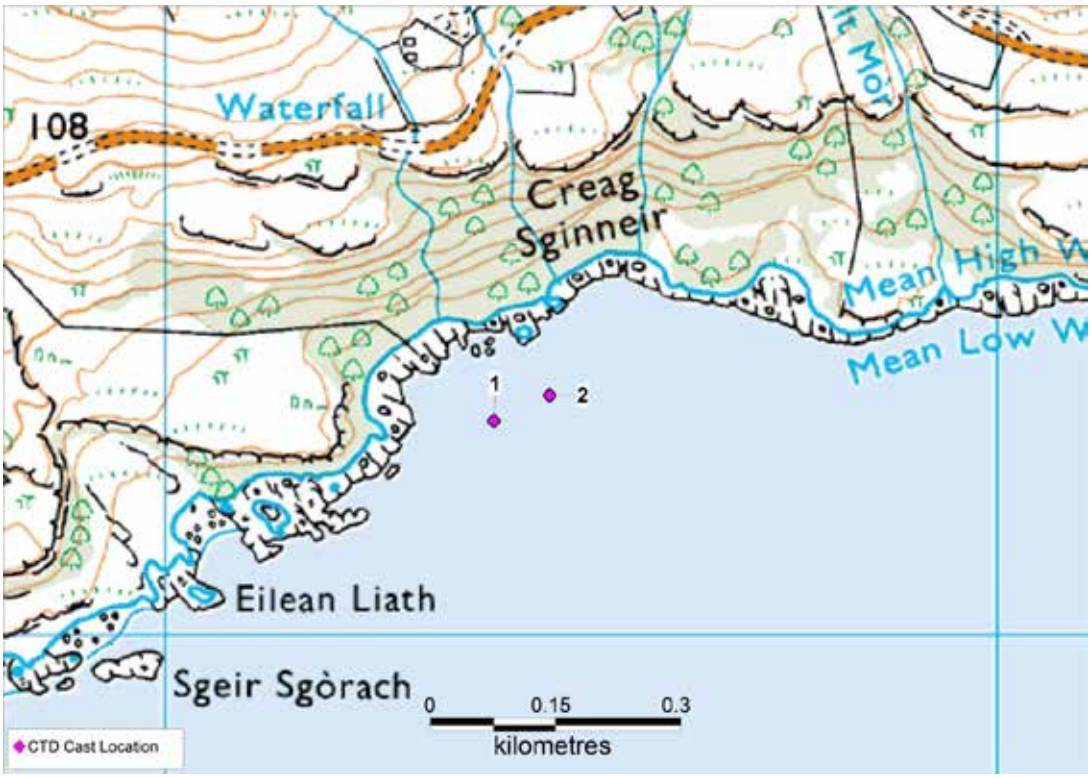

Figure A7.1 Location of CTD cast

CAST 1

Data Header

% Device	10G100653
% File name	10G100653_20140128_094248
% Cast time (local)	09:42:48
% Sample type	Cast
% Cast data	Processed
% Location source	GPS
% Start latitude	56.4774864
% Start longitude	-6.1037745
% Start GPS horizontal error(Meter)	4.230000019
% Start GPS vertical error(Meter)	3.839999914
% Start GPS number of satellites	6
% Cast duration (Seconds)	88
% Samples per second	5
Calibration Date	March 2013
Calibration offset for Temperature	-0.033
Calibration offset for Salinity	0.029

CTD data (calibration offsets applied)

Depth (Meter)	Temperature (Celsius)	Salinity (Practical Salinity Scale)
0.149198556	6.681515935	30.89106908
0.44757721	6.692882673	30.9214058
0.745938116	6.749224605	31.0970744
1.044262499	6.803363945	31.25477341
1.342559484	6.817645087	31.3441943
1.640842934	6.823785031	31.37319535
1.939126174	6.828459135	31.34476036
2.237412941	6.838371519	31.34178858
2.535698655	6.841534382	31.35306604
2.833981276	6.850488283	31.36774199
3.132257344	6.86827785	31.41162505
3.430524064	6.886125158	31.45217423
3.728785798	6.897572738	31.45695679
4.027045016	6.907504958	31.474642
4.325299418	6.922587186	31.50012084
4.623546693	6.941804543	31.53952924
4.921786596	6.975223971	31.57021641
5.219998171	7.055148267	31.80291041
5.518134274	7.176501441	32.26081579
5.816192318	7.27827654	32.52066826
6.114219236	7.367526731	32.56329708
6.412240774	7.406551699	32.58721081
6.710253779	7.438340516	32.64746687
7.008248976	7.458127738	32.74924776
7.306227023	7.489591147	32.80373826
7.604192805	7.522855675	32.86518305
7.902149884	7.541948803	32.88632859
8.200101283	7.556956071	32.91803247
8.498048112	7.567684025	32.92798743
8.795992461	7.579866242	32.9408649
9.093932258	7.590808428	32.96902885
9.391868265	7.597689702	32.97428214
9.689801998	7.600706422	32.98772815
9.98773393	7.605910947	32.98854619
10.28566582	7.59723292	32.98442148
10.7322639	7.607748586	32.98565246

Cast 2

Data Header

% Device	10G100653
% File name	10G100653_20140128_095643
% Cast time (local)	09:56:43
% Sample type	09:56:43
% Cast data	Cast
% Location source	Processed
% Start latitude	56.4778018
% Start longitude	-6.1027054
% Start GPS horizontal error(Meter)	3.75
% Start GPS vertical error(Meter)	4.630000114
% Start GPS number of satellites	7
% Cast duration (Seconds)	89.8
% Samples per second	5
Calibration Date	March 2013
Calibration offset for Temperature	-0.033
Calibration offset for Salinity	0.029

CTD data (calibration offsets applied)

Depth (Meter)	Temperature (Celsius)	Salinity (Practical Salinity Scale)
0.149168076	6.679759644	31.15706977
0.447453247	6.754852504	31.47808517
0.745703088	6.79326422	31.52520262
1.043941323	6.841070895	31.59048189
1.342165282	6.867795379	31.65903948
1.640381854	6.8703266	31.65678289
1.938596087	6.874880269	31.67760808
2.236806564	6.884481185	31.68889441
2.535016195	6.887819752	31.6841162
2.833223076	6.889743204	31.71076572
3.131424619	6.905521004	31.73062847
3.429623755	6.916419605	31.73320178
3.72782198	6.92065047	31.73807686
4.026019043	6.927297903	31.74214009
4.32421416	6.933011393	31.75410132
4.622406625	6.940331858	31.76445743
4.920598063	6.949247634	31.76276754
5.218783474	6.969181953	31.81889144
5.516951955	7.021273758	31.91972561
5.815093797	7.079949831	32.06732143
6.1131942	7.155301294	32.30174018
6.411257968	7.234953964	32.41123785
6.709292896	7.295420889	32.57527114
7.00728729	7.332759415	32.78002671
7.305248351	7.394970658	32.88155338
7.603186858	7.44831266	32.99496925
7.901102945	7.482737527	33.09054109
8.199008303	7.511765692	33.09730011
8.496914017	7.522642931	33.09155537
8.794818919	7.530152785	33.10471332
9.092720397	7.535258214	33.12081991
9.390619747	7.534964	33.12122589
9.688516622	7.541048066	33.1405394
9.986406614	7.545003329	33.1803386