Scottish Sanitary Survey Programme

Sanitary Survey Report

Production Area: Loch Eil, Loch Eil: Eil, & Loch Eil: Fassfern

SIN: HL 134, HL 135 & HL 136

Date: February 2012

Cefas

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Report Distribution – Loch Eil

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I. Executive Summary

A sanitary survey was undertaken at Loch Eil: Fassfern on the basis of failure assessment of historical results against classification for sites subject to classification changes since 2006. The Loch Eil and Loch Eil: Eil production areas were also considered due to their proximity. Loch Eil is located in Lochaber in western Scotland. It stretches west from the northern end of Loch Linnhe, connected by a narrow neck of water called 'The Narrows'. The large town of Fort William lies just outside the loch to the east, at the head of Loch Linnhe. A holiday park and Outward Bound centre on the northeastern shore of Loch Eil experience relatively large numbers of visitors. The population locally will be highest during the summer holiday season, from July to September.

The Loch Eil and Loch Eil: Fassfern production areas are used for long-line mussel aquaculture. The Loch Eil production area consists of two active long-line mussel farms located on the south side of the loch and the Loch Eil: Fassfern production area consists of a single active long-line mussel farm on the northern shoreline of the loch. The Loch Eil: Eil production area had no rafts or long lines installed at the time of the shoreline survey, although lines may be installed in the future.

The eastern end and northern shores of the loch are most likely to be impacted by human sewage, particularly the Fassfern site which is located near a public septic tank. The discharge from the Outward Bound centre will also contribute to contamination levels at the eastern end of Loch Eil. The nearest large sewage discharges are located just outside the production areas, to the east of The Narrows. Most properties around Loch Eil itself appear to be on private septic tanks discharging to land or soakaway. There is likely to be greater volumes of sewage during the summer months when the tourist population is highest.

Based on the numbers and distribution of animals observed during the shoreline survey, diffuse faecal contamination from sheep, is likely to be significant. Direct deposition of droppings at the shoreline and around the large numbers of local fresh watercourses will impact on water quality at the fishery, particularly as the shellfish farms are located quite close to shore. Bacterial loadings to the many freshwater inputs to the loch under rainfall conditions are high and pose a potential source of faecal contamination at all of the fisheries. Gulls and deer are likely to contribute to background levels of faecal contamination in Loch Eil. Gulls on mussel floats are likely to deposit droppings direct to the fishery.

Analysis of historical results suggests that there has been some increase in the general level of *E. coli* in mussels over time for all three production areas. Significant seasonal variation was seen in *E. coli* levels in mussels, with highest results in summer and autumn. Although no clear link was established between results and sources, an increase in human and livestock populations during this time is thought to be the most likely reason for the

increase. A significant correlation was found between *E. coli* result and rainfall in the previous 2 days for Loch Eil: Fassfern and Loch Eil: Eil but not for Loch Eil. A significant positive correlation was found between *E. coli* result and rainfall in the previous 7 days for Loch Eil but not for Loch Eil: Fassfern or Loch Eil: Eil although the probabilities for the latter were borderline. A significant correlation was seen between *E. coli* results and water temperature at Loch Eil, with higher results in warmer temperatures. The greatest number of results exceeding 4600 *E. coli* MPN/100 g was seen at Loch Eil: Eil.

Recommendations

Analysis of historical monitoring results against environmental factors suggests that the three areas are subject to different contaminating influences and therefore it is recommended that they continue to be monitored as separate production areas. Although the site naming is clear, the naming of production areas is confusing and therefore it is suggested that the Loch Eil: Eil production area be renamed as Loch Eil: East to allow for clearer distinction from the Loch Eil production area.

Loch Eil

No change is recommended to the production area boundaries which will be retained as the area bounded by lines drawn between NN 0100 7839 to NN 0100 7730 extending to MHWS. It is recommended that the RMP be revised to NN 0052 7753.

Loch Eil: Fassfern

It is recommended that the production area boundary be curtailed on the western side to exclude the discharge from the Fassfern septic tank and along the south shore to exclude discharges from a private septic tank and land fill. Recommended boundaries are described as the area bounded by lines drawn between NN 0260 7842 to NN 0275 7709 and NN 0275 7709 to NN 0444 7725 and NN 0444 7725 to NN 0440 7834 and extending to MHWS to the north. It is recommended the RMP be revised to NN 0295 7815.

Loch Eil: Eil (*Loch Eil East*)

It is recommended that the production area boundary be curtailed at the western edge to exclude the area around the mouth of the watercourse to which the Outward Bound centre sewage discharges. Recommended boundaries are the described as the area bounded by lines drawn between NN 0579 7806 to NN 0516 7715 and between NN 0700 7755 and NN 0700 7682 and extending to MHWS. It is recommended the RMP be retained at the sampling bag currently situated along the southeastern shore of the Crown Estate lease area, at NN 0598 7730. It is recommended that the location be re-evaluated when the mussel fishery has been put in place.

A stability assessment was carried out on all three areas: the results did not support reduced monitoring frequency for any of the sites therefore continued monthly monitoring is recommended at all sites. Further information on sampling depth and tolerance can be found in the sampling plan, and in report Section 17, Recommendations.

II. Sampling Plan

PRODUCTION AREA	Loch Eil	Loch Eil: Fassfern	Loch Eil: Eil (*Loch Eil East*)
SITE NAME	Duisky	Fassfern	Loch Eil
SIN	HL 134 216 08	HL 136 219 08	HL 135 218 08
SPECIES	Common mussel	Common mussel	Common mussel
TYPE OF FISHERY	Long-line aquaculture	Long-line aquaculture	None at present- to be long-line aquaculture
NGR OF RMP	NN 0052 7753	NN 0295 7815	NN 0598 7730
EAST	200520	202950	205980
NORTH	777530	778150	777300
TOLERANCE (M)	40	40	20
DEPTH (M)	2-3	2-3	2-3
METHOD OF SAMPLING	Hand	Hand	Hand
FREQUENCY OF SAMPLING	Monthly	Monthly	Monthly
LOCAL AUTHORITY	Highland Council	Highland Council	Highland Council
AUTHORISED SAMPLER(S)	Stephen Lewis	Stephen Lewis	Stephen Lewis
LOCAL AUTHORITY LIAISON OFFICER	Alan Yates	Alan Yates	Alan Yates

III. Report

1. General Description

Loch Eil is located in Lochaber in western Scotland. It stretches west from the northern end of Loch Linnhe, connected by a narrow neck of water called 'The Narrows'. The loch is approximately 10 km in length and 1.2 km at its widest section, and has a maximum depth of 71 m. The large town of Fort William lies just outside the loch, at the head of Loch Linnhe. A sanitary survey was undertaken at Loch Eil: Fassfern on the basis of failure assessment of historical results against classification for sites subject to classification changes since 2006. The Loch Eil and Loch Eil: Eil production areas were also considered due to their proximity within the same water body.

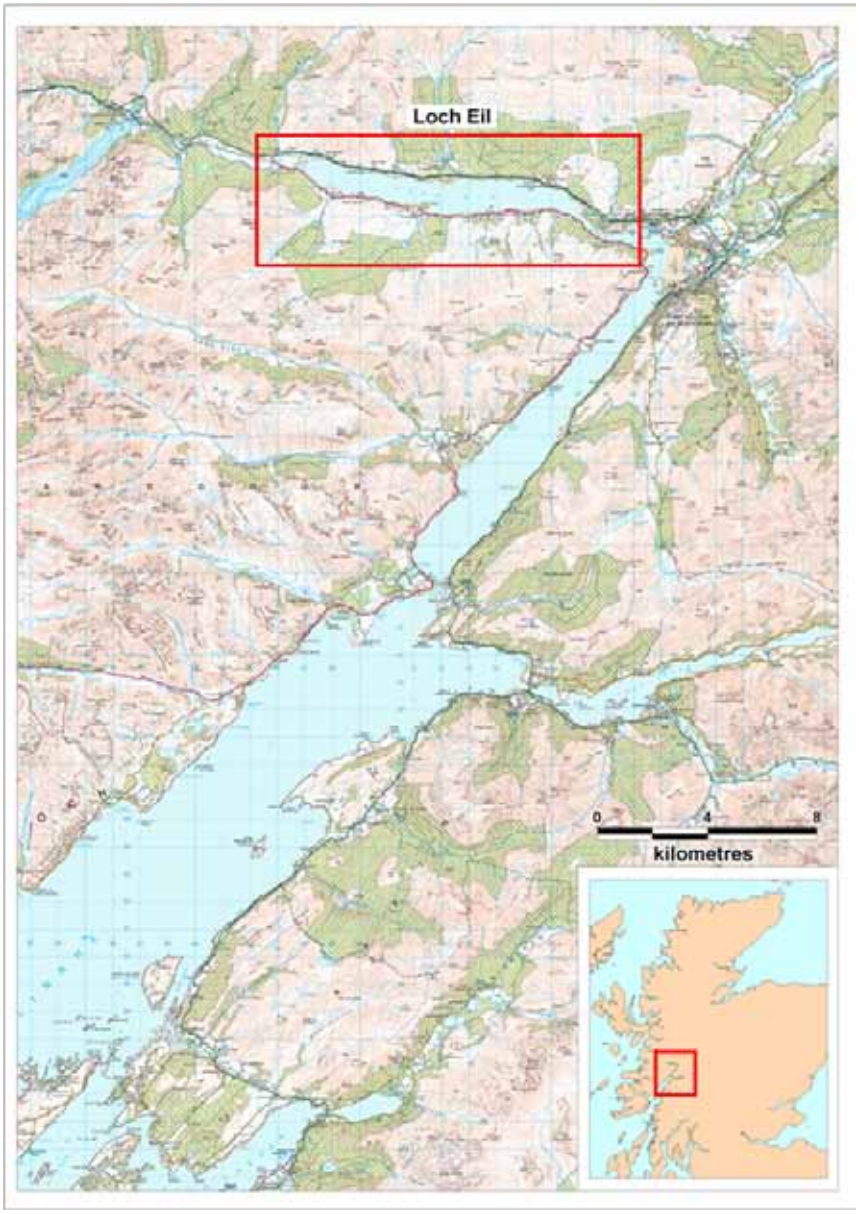


Figure 1.1 Location of Loch Eil

2. Fishery

Details of the three classified production areas surveyed are identified below in Table 2.1. All are current or intended long-line mussel farms.

Table 2.1 Area shellfish farms

Production Area	Site Name	SIN	Harvester	Nominal RMP
Loch Eil	Duisky	HL 134 216 08	Alan & Lawrie Byrne	NN 005 786
	Garvan	HL 134 217 08		
Loch Eil: Eil	Loch Eil	HL 135 218 08	James MacLean	NN 062 773
Loch Eil: Fassfern	Fassfern	HL 136 219 08	Alan & Lawrie Byrne	NN 038 783

There is significant discrepancy between the locations of the Loch Eil: Garvan and Loch Eil: Duisky nominal RMP and the recorded sampling points. The nominal RMP is stated as being located on the opposite shoreline to the shellfish farms. The current production area boundaries as stated in the 2011/12 classification document are identified in Table 2.2 below.

Table 2.2 Production area boundaries

Production Area	Boundary Description
Loch Eil	Area bounded by lines drawn between NN 0100 7839 to NN 0100 7730 extending to MHWS
Loch Eil: Eil	Area bounded by lines drawn between NN 0070 7682 to NN 0700 7755 and NN 0440 7724 to NN 0440 7834
Loch Eil: Fassfern	Area bounded by lines drawn between NN 0440 7724 to NN 0440 7834 and NN 0100 7839 to NN 0100 7730

The Loch Eil production area consists of two active long-line mussel farms located approximately 1 km from one another on the south side of the loch. The Garvan site is composed of six double-headed lines with 7 – 10 m droppers and the Duisky site is composed of five double-headed lines with 7 to 10 m droppers. Both sites will be changing to 6 m droppers in the future. This production area lies west of the Loch Eil designated shellfish growing water.

The Loch Eil: Fassfern production area consists of a single active long-line mussel farm called Fassfern on the northern shoreline of the loch. It was observed during the shoreline survey that there are two separate (west and east) areas each containing 6 double headed continuous lines. The outer line (furthest from shore) in each area had drifted and was due to be moved further inshore and to the east.

The Loch Eil: Eil production area had no rafts or long lines installed at the time of the shoreline survey. The rafts had been removed and some of the equipment was observed on the shoreline. A single dropper line is kept attached to a moored boat for the purposes of sampling. The sampling officer

stated that the harvester had identified the intention to replace the rafts with lines in the future.

Both the Loch Eil: Fassfern and Loch Eil: Eil production areas lie within the Loch Eil designated shellfish growing water.

Figure 2.1 shows the relative positions of the mussel farms, production areas, shellfish growing waters, RMP and the seabed lease areas.

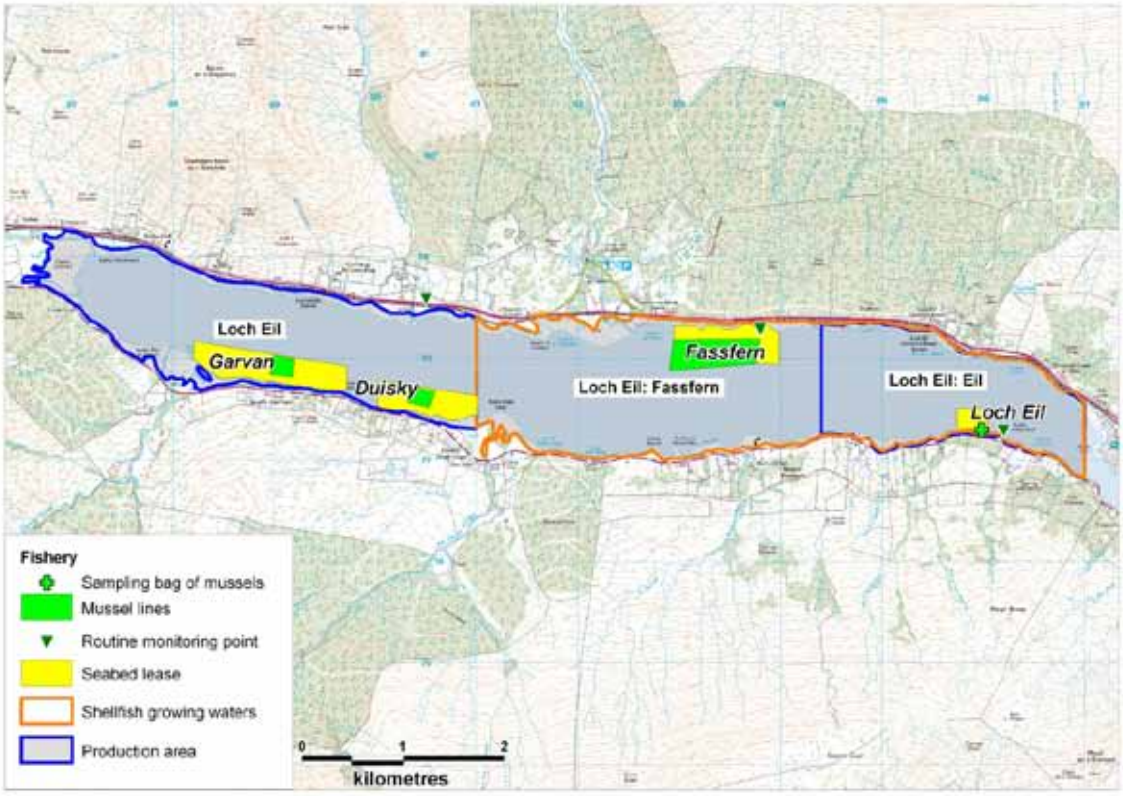


Figure 2.1 Loch Eil shellfish farms

3. Human Population

Information was obtained from the General Register Office for Scotland on the population within the census output areas in the vicinity of Loch Eil. The last census was undertaken in 2001.

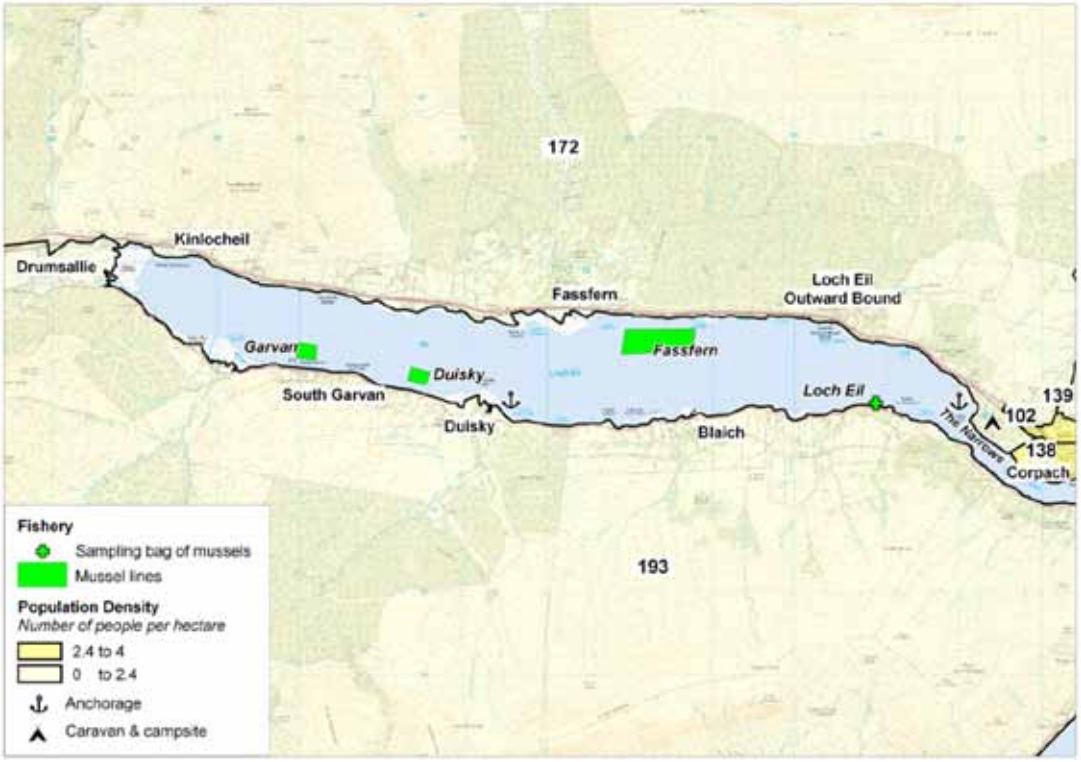


Figure 3.1 Population map of Loch Eil

Figure 3.1 shows that population density is low for the census output areas immediately adjacent to Loch Eil. There are small settlements along both the north and south shores of the loch. The settlements nearest to the fisheries are South Garvan and Duisky on the southern shoreline and Fassfern on the northern shoreline. The village of Corpach is located along the north shore to the east of The Narrows. The population in the surrounding area is spread amongst five census output areas, as listed in Table 3.1.

Table 3.1 Census output areas: Loch Eil

Output area	Population	Area (km^2)
60QT000146	193	86.4
60QT000147	172	127.2
60QT000148	139	42.6
60QT000439	102	0.25
60QT000440	138	0.57
Total	**744**	

Two of these areas border directly on Loch Eil. The large majority of the population for the area directly bordering the north shore of Loch Eil is located along the main road that runs along the shoreline of the loch. Aside from

Kinlocheil, Fassfern and the Loch Eil Outward Bound centre, there are no other settlements within the northern 60QT000127 census output area.

The southern census output area (60QT000146) extends south of the area shown and encompasses part of the eastern shoreline of Loch Linnhe, where there are a further two small settlements.

The remaining three areas are associated with the settlement of Corpach. The census output area 60QT000148 (population 139) covers a large inland area north of Corpach and the majority of its population is located outwith the area (a small corner of the area is shown in Figure 3.1). Three further output areas associated with Corpach lie east of the area shown in Figure 3.1 and are not listed in Table 3.1.

Approximately 3.5 km east of The Narrows, and not shown within the area of the map in Figure 3.1, is the town of Fort William which has a population of 9908, including Corpach. The Fort William area has a large number of hotels, guest houses and other forms of tourist accommodation.

Around the shores of Loch Eil, the main tourist centres are the Outward Bound centre and the Linnhe Lochside holiday park at the western end of The Narrows, on the northern side of the loch. The Linnhe Lochside holiday park has over 100 chalets and static caravans, as well as pitches for mobile caravans and tents, and therefore may accommodate in excess of 500 visitors at peak times. The Outward Bound centre provides accommodation for up to 119 people (http://www.outwardbound.org.uk/images/pdf/facility-sheets/loch-eil.pdf, accessed 28/02/2012).

In addition, there are also a small number of other activity centres and guesthouses/B&Bs. The main season for visitors is from July to September with a marked peak in August. There is a picnic area on the northern shoreline at Fassfern. This does not have toilet facilities.

No marinas or facilities for visiting yachts were identified within Loch Eil, but there are anchorages reported west of the narrows along the north shore, and at Duisky just to the east of the mouth of a burn, presumed to be An Dubh Uisge (Clyde Cruising Club, 2007). There is a port and moorings at Corpach, to the east of, and immediately outside of, The Narrows.

Overall, the population is highest around the eastern end of the loch, and along the northeastern shore where the holiday park and Outward Bound centre draw relatively large numbers of visitors. The population within the area around the loch will be higher from July to September, and highest in August. The anchorage at Duisky is over 1 km from the mussel farm, and therefore may not have a significant impact on water quality there.

4. Sewage Discharges

Information on sewage discharges to the area was sought from Scottish Water and the Scottish Environment Protection Agency (SEPA). Scottish Water identified the following public sewerage discharges in the vicinity of Loch Eil. These are identified in Table 4.1. All discharges are shown mapped in Figures 4.1 and 4.2.

Table 4.1 Discharges identified by Scottish Water

Consent Ref No.	NGR of discharge	Discharge Name	Discharge Type	Level of Treatment	Consented flow	Consented Design PE
-	NN 0221 7809	Fassfern ST	Continuous	Septic tank	-	-
CAR/L/1003071	NN 0890 7659	Corpach WWTW	Continuous	Secondary	525 m3/day	2100
CAR/L/1003071	NN 0890 7659	Corpach Beach SPS CSO/EO	Intermittent	Screened	25 l/sec	-
CAR/L/1003071	NN 0890 7659	Corpach Works SPS CSO/EO	Intermittent	Screened	25 l/sec	-
-	NN 0790 7695	Fort Wlm Annat Point SPS EO	Intermittent	Screened	-	-
-	NN 0952 7675	Corpach Butcher's Shop No. 1 SWO	Intermittent	-	-	-
-	NN 0988 7672	Corpach, Hillview Drive No. 3 SWO	Intermittent	-	-	-
CAR/L/1001897	NN 1020 7510	Caol Spit WWTW	Continuous	Secondary	4598 m3/day	23500
CAR/L/1001897	NN 1020 7510	Caol Spit WWTW SSSO	Intermittent	Screened	-	23500
CAR/L/1001897	NN 1020 7510	Caol Spit WWTW SPS EO	Intermittent	Screened	-	23500
CAR/L/1001897	NN 1020 7510	Caol Spit WWTW CSO	Intermittent	Screened	-	23500
-	NN 1025 7415	Fort William Tweedale CSO/EO	Intermittent	-	-	-
-	NN 0983 7365	Fort William Opp Westend Hotel CSO	Intermittent	Screened	1440	-
-	NN 1195 7425	Fort William Claggan Road CSO	Intermittent	-	-	-

- Data not provided

Sanitary data was provided for January 2010 to March 2011 for the Corpach wastewater treatment works (WWTW) effluent and for May 2010 to March 2011 for the Caol Spit WWTW. All reported samples were below the 25 mg/l net discharge limit for BOD specified under the Urban Waste Water Treatment Directive (91/71/EEC). No microbiological data was provided. No information on spill frequency was provided for any of the intermittent discharges. No information relating to the consented flow volume or design population equivalent (PE) was provided for the Fassfern septic tank. Feedback provided by Scottish Water subsequent to the draft of this report identified that the populations served by the treatment works in this area were reviewed and the current populations served are: Caol Spit WWTW – 16000, Corpach WWTW – 2000, and Fassfern Septic Tank – 21. These figures represent the population currently connected to the works, while the consented design PE usually provides scope for future population growth. Scottish Water report an ongoing refurbishment project at Corpach WWTW, and that as part of that project they have identified that the impact of the discharge is compliant with the design standard established by SEPA (100 FC/100 ml) at the eastern boundary of the designated shellfish growing water. While the parameters to which public sewage discharges must adhere are predicted to be met in this case, there is a difference between the required water quality to meet shellfish hygiene standards and that identified by SEPA as suitable for meeting the

SGW standard. A recent study examining the relationship between faecal indicator concentrations in shellfish flesh and overlying water in England and Wales predicted compliance with the class B threshold (≤4600 *E. coli*/100g with 90% probability) in common mussels at 33 *E. coli* cfu/100 ml in overlying waters (Campos, et al 2011). This broadly concurs with a study on equivalence between shellfish and water standards, which identified a value of 50 *E. coli*/100 ml in water for 90% compliance with class B (EU Scientific Veterinary Committee Working Group on Faecal Coliforms in Shellfish 1996).

Only the Fassfern Septic Tank discharges directly to Loch Eil. The remainder of the assets identified by Scottish Water discharge to the head of Loch Linnhe, outside the entrance to Loch Eil. The Corpach WWTW discharges 2.3 km away from the eastern boundary of the Loch Eil: Eil production area, which forms the easternmost boundary of the Loch Eil shellfisheries. The nearest intermittent discharge, the Annat Point SPS EO, lies 1.2 km east of the boundary. Caol Spit WWTW, and its associated CSOs, lie over 3.5 km to the east of the boundary.

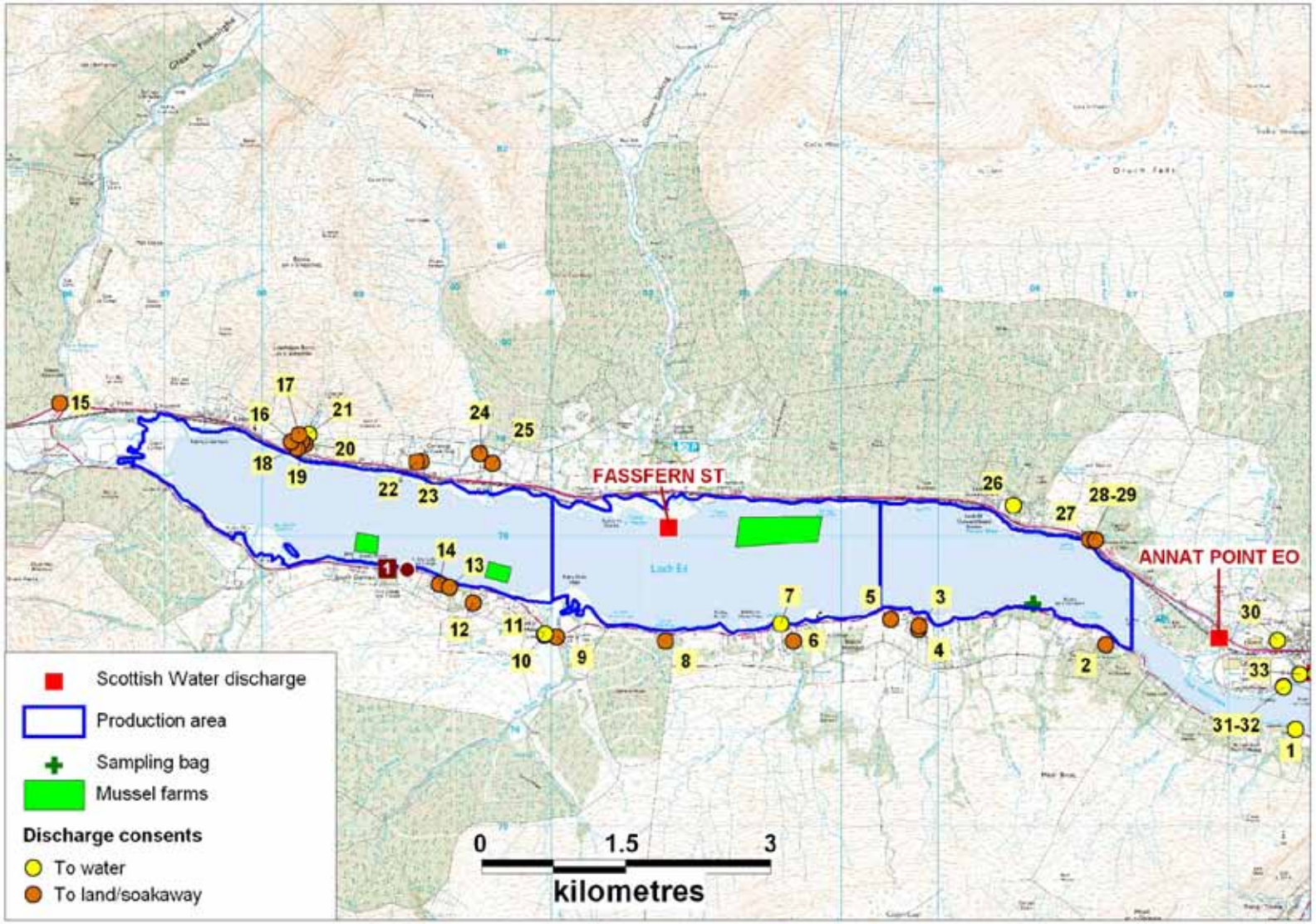


Figure 4.1 Map of discharges for Loch Eil

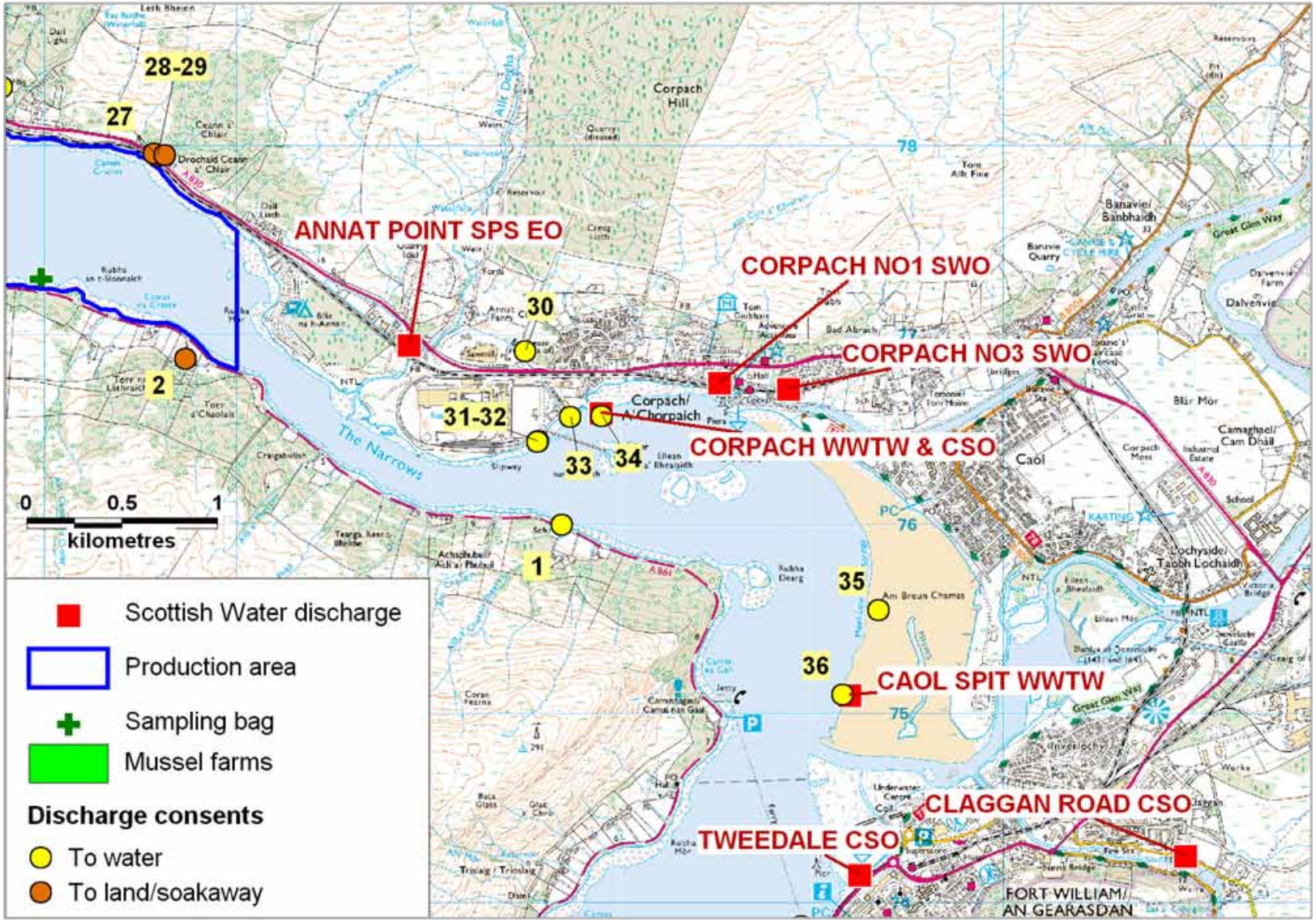


Figure 4.2 Map of discharges – Fort William

SEPA provided information on a relatively large number of consented discharges. Only those located along the Loch Eil shore, or discharging to the sea either within The Narrows or the uppermost extent of Loch Linnhe are listed in Table 4.2, as these are likely to be of greatest significance to the fishery.

Table 4.2 Discharge consents identified by SEPA

No.	Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Consented/ design PE	Discharges to
1	CAR/R/1079163	NN 0870 7600	Continuous	Septic tank	-	10	The Narrows
2	CAR/R/1041789	NN 0673 7688	Continuous	Septic tank		5	Soakaway
3	CAR/R/1039643	NN 0480 7707	Continuous	Septic tank		5	Land
4	CAR/R/1039294	NN 0480 7703	Continuous	Septic tank		5	Land
5	CAR/R/1078700	NN 0451 7714	Continuous	Septic tank		6	Soakaway
6	CAR/R/1039645	NN 0350 7691	Continuous	Septic tank		6	Land
7	CAR/R/1016662	NN 0337 7709	Continuous	Septic tank		10	Loch Eil
8	CAR/R/1045992	NN 0218 7691	Continuous	Septic tank		5	Soakaway
9	CAR/R/1051085	NN 0105 7696	Continuous	Septic tank		5	Soakaway
10	CAR/L/1001925	NN 0093 7698	Landfill leachate	wetland	-	NA	-
11	CAR/R/1081641	NN 0093 7699	Continuous	Septic tank		6	Allt Dubhaig
12	CAR/R/1077216	NN 0019 7731	Continuous	Septic tank		6	Soakaway
13	CAR/R/1064786	NM 9995 7747	Continuous	Septic tank		5	Soakaway
14	CAR/R/1064780	NM 9984 7750	Continuous	Septic tank		5	Soakaway
15	CAR/R/1080324	NM 9591 7937	Continuous	Septic tank		5	Soakaway
16	CAR/R/1064977	NM 9831 7898	Continuous	Septic tank		7	Soakaway
17	CAR/R/1064978	NM 9838 7905	Continuous	Septic tank		6	Soakaway
18	CAR/R/1039905	NM 9837 7891	Continuous	Septic tank		7	Soakaway
19	CAR/R/1038720	NM 9842 7898	Continuous	Septic tank		5	Soakaway
20	CAR/R/1038717	NM 9845 7896	Continuous	Septic tank		7	Soakaway
21	CAR/R/1009424	NM 9849 7905	Continuous	Septic tank		6	Allt na Criche
22	CAR/R/1058773	NM 9960 7877	Continuous	Septic tank		7	Soakaway
23	CAR/R/1010628	NM 9965 7877	Continuous	Septic tank		7	Soakaway
24	CAR/R/1019780	NN 0026 7885	Continuous	Septic tank		5	Land
25	CAR/R/1038047	NN 0039 7875	Continuous	Septic tank		5	Soakaway
26	CAR/L/1002139	NN 0578 7832	Continuous	-	1	1	Allt An Fhuadh
27	CAR/R/1038919	NN 0657 7797	Continuous	Septic tank		6	Soakaway
28	CAR/R/1026361	NN 0659 7795	Continuous	Septic tank		5	Soakaway
29	CAR/R/1060019	NN 0663 7796	Continuous	Septic tank		6	Soakaway
30	CAR/L/1002109	NN 0851 7692	Continuous	sawmill	1*	-	River Lochy
31	CAR/R/1024589	NN 0857 7644	Continuous	trade		-	The Narrows
32	CAR/R/1019745	NN 0857 7644	Continuous	STW		10	Loch Linnhe
33	CAR/L/1004065	NN 0874 7657	-	-	1*	-	Loch Linnhe
34	CAR/L/1003071	NN 0891 7658	Continuous Intermittent	Secondary/ screened	525	2100	Loch Linnhe
35	CAR/L/1001904	NN 1035 7555	Intermittent	Screened		-	Loch Linnhe
36	CAR/L/1001897	NN 1016 7510	Continuous	STW	4598	23500	Loch Linnhe

* mean daily flow (m^3/day)

Although there are public sewerage works at Corpach (No. 34) and Fort William (No. 36), the majority of properties at Loch Eil appear to be on private septic tanks or package treatment works, most of which discharge to land or soakaway. Discharge No. 7 relates to two properties on the south shore of the loch. No septic pipe was observed in this vicinity, however a number of permanent caravans and constructed homes were observed.

Number 32 relates to a septic discharge from an industrial estate east of The Narrows. The consent refers to this as an STW, or Sewage Treatment Works, however no information was provided on the treatment level applied to this discharge.

No consent information was provided by SEPA for the Fassfern Septic Tank listed in Table 4.1. No consent was identified for the Lochside Holiday Park. It is not clear whether this facility is connected to the mains sewerage at Corpach or a private septic tank.

Discharge number 26 pertains to the Outward Bound centre. The consent was identified as being for a sewage treatment works, however no information was provided on treatment level. It was identified as having a consented DWF of 1 m^3/day and a PE of 1. The flow corresponds roughly with a population equivalent of 10, which is approximately 1/11th of the centre's capacity. It is possible that this is based on an average occupancy, however it should be presumed that the centre may discharge more during periods of high occupancy.

Corpach paper mill site is currently being redeveloped by BSW timber into an integrated timber plant. A discharge consent was received for trade effluent only from the sawmill, however this does not specify whether there is a sanitary component and if so, what proportion of the volume would be septic. It is not clear whether the relocated sawmill would continue to use the same trade discharge location, however as it is being expanded as well the discharge would be expected to accommodate a larger volume and larger workforce. Therefore, there is the potential for an increase in impact from this source.

Discharge number 10 relates to what is referred to as 'wetlands effluent' from Duisky landfill. The discharge location relates to a watercourse, Allt Dubhaig. Duisky landfill is reported to cover an area of approximately 40 hectares and receives non-hazardous wastes. It is not clear what level of treatment is provided by the wetlands. A water sample taken from the Allt Dubhaig during the shoreline survey returned a result of 200 *E. coli*/100 ml, indicating moderate levels of faecal contamination, however it is not possible to say what proportion, if any, of the contamination was attributable to the landfill.

Information was supplied for fewer discharges than there are properties along the south shore of the loch. The consents identified for the shoreline nearest the Garvan and Duisky sites were predominantly for discharge to soakaway the nearest of these discharge to soakaway. However, as the properties on the shoreline adjacent to the mussel farms are situated within 100 m of the shore (and presuming the soakaways are a similar distance from shore) there is a risk of faecal contamination arising from these sources if the soakaway systems are not properly maintained and sewage is carried via rainfall runoff or overland flow to the loch. No evidence of this was observed at the time of shoreline survey.

Additional dwellings are under construction along the north shore of the loch, and it is not clear whether these will be connected to mains sewerage or private septic tanks.

Sewage infrastructure recorded during the shoreline survey is listed in Table 4.3.

Table 4.3 Discharges and septic tanks observed during shoreline surveys

No.	Date	NGR	Description
1	20/09/2011	NM 99511 77652	Rusty outfall pipe – no flow or evidence of recent flow, appears redundant

Only one outfall pipe was observed during the shoreline survey, and this appeared to be redundant. It did not appear to relate to any of the identified consented discharges. During the shoreline survey, local concerns were identified about sewage from caravans at Fassfern entering the burn and in turn the loch near the Fassfern mussel farm. It was also noted during the shoreline survey that the harvester had identified plans to incorporate toilet facilities on the service barge, though it had not yet been decided whether this would incorporate chemical treatment or a holding tank. It must be noted that even if a holding tank is incorporated, there is the potential for spills either due to failure of the tank, overflow of capacity, or spill during pumpout and any such spills when the barge was in situ at the farm would have a significant impact on the bacteriological quality of the mussels in the vicinity.

Discharges for Loch Eil are shown mapped in Figure 4.1, while relevant discharges for the Fort William area are shown in Figure 4.2.

Assessment

The largest sewage discharges to the area lie outside Loch Eil, to the east of The Narrows. Both receive secondary treatment. However, they have a combined population equivalent of over 25000. An estimate of the potential loading from these sources was calculated using a combined consented dry weather flow (DWF) of 5123 m^3/day and a typical geometric mean faecal coliform concentration of $3.3x10^5$ cfu/100ml for secondary treated sewage (Kay *et al*, 2008). The resulting estimated loading was 1.7×10^{13} faecal coliforms/day to the waters of upper Loch Linnhe. Any overflow discharges from CSOs would be expected to have a much greater impact due to the lack of treatment.

The only public sewage discharge to Loch Eil itself is from the Fassfern septic tank (connected population 21) and this is reported to discharge to the loch approximately 700 meters west of the Fassfern site. The discharge from the Outward Bound centre, depending on its treatment level and true volume, is likely to further contribute to contamination levels at the eastern end of Loch Eil, particularly along the northern shore. Volumes of sewage discharged are likely to be significantly higher during summer, when the area population swells with visitors. Although no spill information was provided, spills from CSOs are likely to add significantly to bacterial loads in the loch.

The southern shore around the Garvan and Duisky sites has few discharges to water and a number of discharges to soakaway, which may if not maintained lead to contamination of the loch near to the shore. Any contamination arising from the landfill will be most likely to impact the Duisky site.

The eastern end and northern shores of the loch are most likely to be impacted by human sewage, and in particular the Fassfern site which is located nearest a public sewage discharge. There is likely to be seasonal variation in the input of human sewage to the loch, with greater volumes of sewage likely during the summer months when the tourist population is highest. It was not possible to evaluate whether there would be seasonal variation in combined sewer overflows.

5. Geology and Soils

Geology and soil types were assessed following the method described in Appendix 2. A map of the resulting soil drainage classes is shown in Figure 5.1. Areas shaded red, yellow and orange indicate poorly draining soils while areas shaded blue indicate more freely draining soils. The areas shaded grey indicate built-up areas.

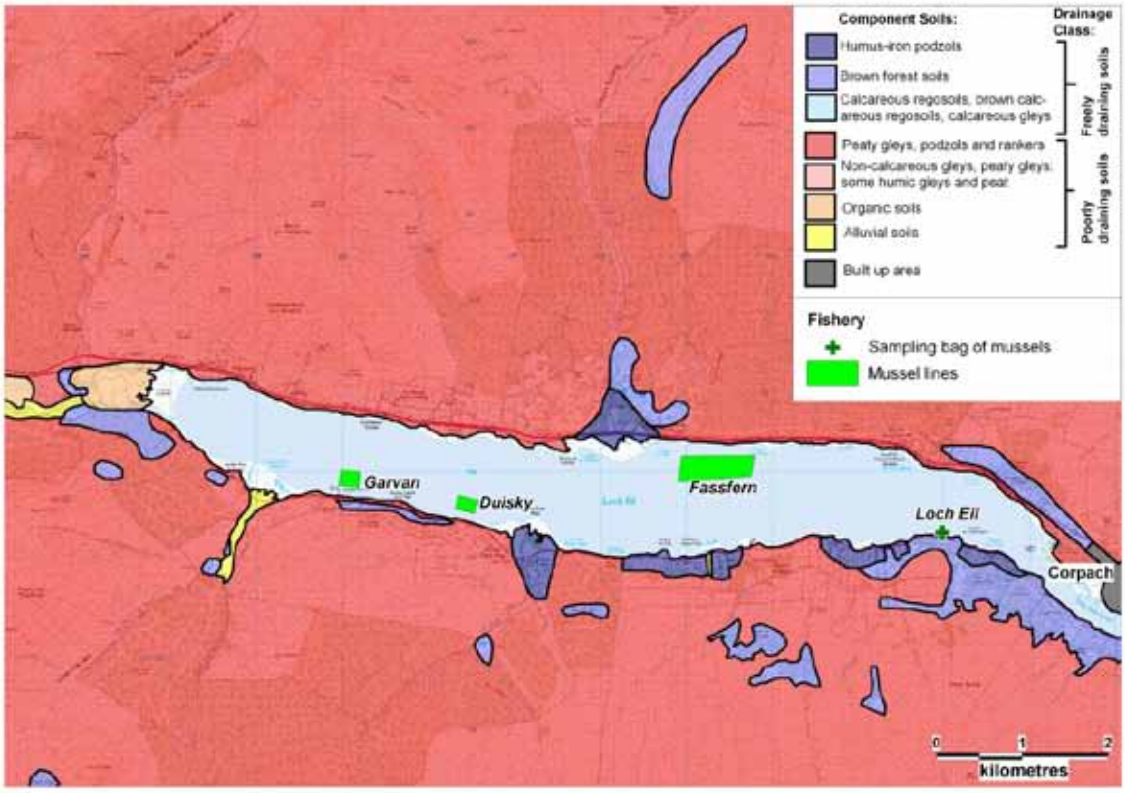


Figure 5.1 Component soils and drainage classes for Loch Eil

The predominant soil type present in this area is classed as poorly draining. It is composed primarily of peaty gleys, podzols and rankers. This soil type covers the majority of the land inland, small sections of the southern shoreline and almost the whole of the northern shoreline.

Small, scattered areas of more freely-draining soils are found around the loch, the most predominantly along the southeastern shore. Small areas of organic and alluvial soils are located near the head of the loch and also along the Garvan River on the south shore. Built-up area is identified around the village of Corpach.

The potential for runoff contaminated with *E. coli* from human and/or animal waste is high along the immediate coastline around Loch Eil, with the exception of parts of the southeast shore and the area around Fassfern.

6. Land Cover

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

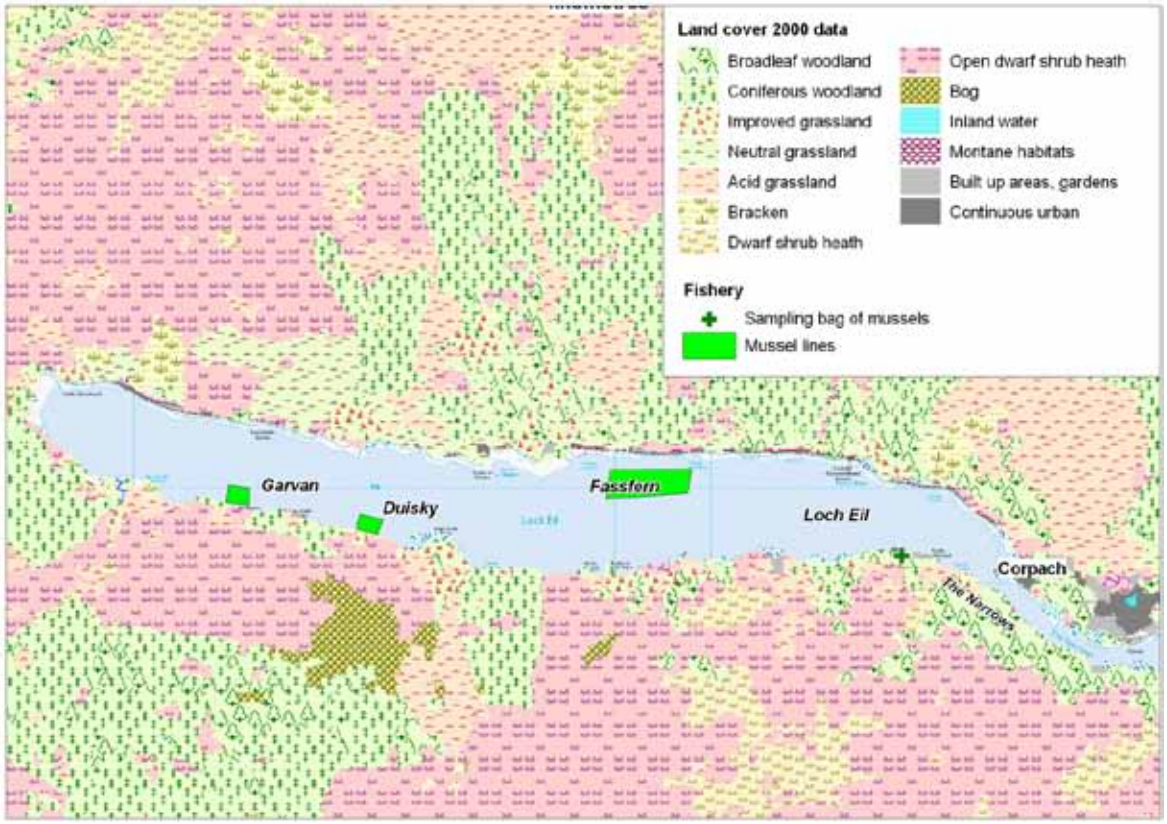


Figure 6.1 LCM2000 class land cover data for Loch Eil

Land cover around Loch Eil is predominantly heath and woodland, with some grassland areas. Improved grassland is present in small sections on the shoreline opposite the shellfish farms. The settlement of Corpach north of The Narrows is represented by the land cover types built up areas, gardens and continuous urban.

Faecal indicator organism export coefficients for faecal coliform bacteria have been found to be highest from developed areas (approximately $2.8x10^9$ cfu km^{-2} hr^{-1}), approximately $8.3x10^8$ cfu km^{-2} hr^{-1} for areas of improved grassland and approximately $2.5x10^8$ cfu km^{-2} hr^{-1} for rough grazing and forested areas (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 large forested areas are likely to be subject to greater rainfall runoff after clear cutting, and this may potentially lead to flushes of faecal contaminants, particularly from deer, to watercourses draining these areas. At the Loch Eil fishery the potential for the highest contribution of faecal coliform bacteria attributable to land cover type is greatest around the built up area at Corpach and where there is improved grassland, in particular adjacent to Duisky and to the northwest of Fassfern.

7. Farm Animals

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 production area. Agricultural census data to parish level was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for the Ardgour and Killmallie parishes. Reported livestock populations for the parishes in 2009 and 2010 are listed in Table 7.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reporting would have made it possible to discern individual farm data. Any entries which relate to less than five holdings, or where two or fewer holdings account for 85% or more of the information, are replaced with an asterisk.

Table 7.1 Livestock numbers in Ardgour and Killmallie parishies 2009 - 2010

	Ardgour 369 km^2				**Killmallie** 870 km^2			
	2009		2010		2009		2010	
	Holdings	Numbers	Holdings	Numbers	Holdings	Numbers	Holdings	Numbers
Pigs	*	*	0	0	*	*	0	0
Poultry	8	67	11	100	21	262	25	323
Cattle	17	306	17	324	31	611	32	631
Sheep	*	*	*	*	25	11230	25	10902
Other horses and ponies	5	17	6	17	10	22	10	22

The Ardgour agricultural parish encompasses an area extending 43 km south of Loch Eil and up to 19 km west of Loch Linnhe. Agricultural census data indicates that relatively low numbers of livestock are kept in this parish. Although there were sheep reported for this parish, no data could be provided due to the small number of holdings.

The Kilmallie parish encompasses two large, separate areas: one extending approximately 21 km north of Loch Eil and the other extending 17 km south along the eastern shore of Loch Eil. Although large numbers of livestock, particularly sheep, were reported for the parish the overall land area covered is very large and the distribution of animals is unlikely to be even.

The only significant source of spatially relevant information was therefore the shoreline survey (see Appendix 6). Observations recorded during the shoreline survey only relate to the time of the site visit on the 19th – 22nd September 2011. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1.

A total of 24 cattle and 66 sheep, as well as tracks and droppings, were observed along the south shore of the loch. Cattle tracks were observed along the river and shore at the head of the loch, though no animals were seen. Substantially more livestock was found along the north shore of the

loch, where 258 sheep and 2 horses/ponies were seen. The majority of these were to the west of the Fassfern site.

The catchment for the area extends on both sides of the loch along a number of large burns, and these areas away from the immediate shoreline were not viewed, therefore more animals may have been present within the catchment.

Based on the numbers and distribution of animals observed during the shoreline survey, a significant proportion of any faecal contamination reaching Loch Eil is likely to be from diffuse, livestock sources. Direct deposition of droppings at the shoreline and in and around watercourses is likely to pose the greatest threat to water quality at the fishery, particularly as the shellfish farms are located quite close to shore. Large numbers of sheep and droppings were observed near the Fassfern site. There is also the potential for direct runoff from the steep hillsides on both sides of the fishery to carry livestock faeces to the waters immediately adjacent to the shellfish farms.

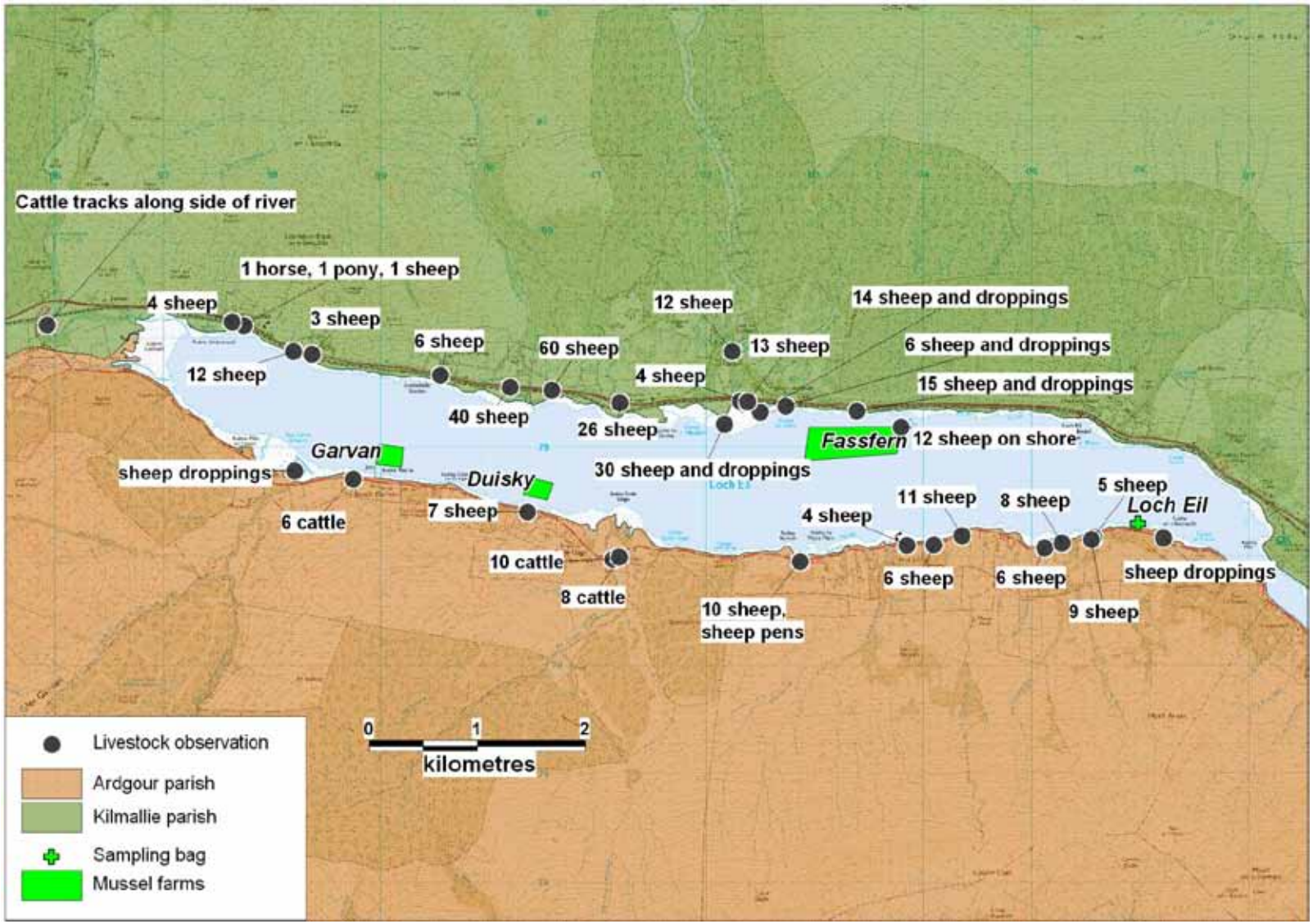


Figure 7.1 Livestock observations at Loch Eil

8. Wildlife

Wildlife may contribute to faecal contamination observed at fisheries. General information on the impacts of wildlife species can be found in Appendix 2. Wildlife species most likely to contribute to faecal contamination of the waters of Loch Eil include birds, deer, and otters.

Birds

Seabird 2000 census data was queried for the area within a 5 km radius of the Loch Eil production areas. This census, undertaken between 1998 and 2002, covered the 25 species of seabird that breed regularly in Britain and Ireland. No records were returned for this area. The closest record was 5.9 km south east of the Fassfern shellfish farm, where a large colony consisting of four species of gull was observed on a small island at the head of Loch Linnhe. The recorded numbers are listed in Table 8.1 below.

Table 8.1 Seabird 2000 counts within 6km of the site.

Common name	Species	Estimated No.*	Method
Herring Gull	*Larus argentatus*	306	Occupied nests
Common Gull	*Larus canus*	132	Occupied nests
Great Black-backed Gull	*Larus marinus*	4	Occupied nests
Black-headed Gull	*Larus ridibundus*	2	Occupied nests

* Counts for occupied nests were doubled to reflect the likely number of individuals

During the shoreline survey, approximately 640 gulls were observed in the vicinity of the Garvan and Duisky mussel lines. Approximately 50 gulls were observed on the mussel floats at the Garvan fishery and a bird scarer was in place to keep the gulls off the work raft at the Duisky fishery. The gulls seemed to be associated with the nearby landfill site, where they would feed, and therefore are likely to be routinely present in the area. In addition to gulls, a small number of swans and oystercatchers were also observed. At the Fassfern fishery to the east of Loch Eil approximately 30 gulls and 2 cormorants were observed on the mussel floats.

Birds nesting nearest the fishery are most likely to contribute diffuse faecal contamination to the area, particularly after rainfall. Birds flying over, feeding in waters at the mussel farms or resting on mussel floats may directly deposit droppings near the mussel lines and so would have a greater impact on water quality when this occurs. At least some of the breeding gulls are likely to be present in the area year round and were observed resting on mussel floats during the shoreline survey. However, their numbers may be higher during the summer nesting season, which is roughly from May to August. Guano deposited around nest areas, however, is likely to wash off with rainfall over a longer period of time.

Wildfowl, such as geese and ducks, are likely to be present in the area though no specific data were found on populations in or near the fisheries.

Seals
Both grey seals (*Halichoerus grypus*) and common or harbour seals (*Phoca vitulina vitulina*) are recorded in Loch Linnhe, and a small number of harbour seals has been recorded in the past in Loch Eil (Special Committee on Seals, 2009). No seals were observed during the shoreline survey. These animals are likely to be present in and around the fishery from time to time and could potentially leave faeces behind, though any effect would be very minor in comparison to other sources.

Deer
Deer are known to be present within the catchment area, though no specific information was available on the probable number of animals. No deer were seen during the shoreline survey. However, given the terrain and wooded cover, there are likely to be significant numbers of deer within the catchment for the loch. Faecal indicator bacteria arising from deer droppings are likely to be carried via rainfall runoff to rivers and streams.

Otters
Otters have been recorded in the area in the past, however no recent records of otter numbers were found. No otters were seen during the shoreline survey. Otters typically defecate in established latrines adjacent to freshwater courses. Loch Eil has a large number of rivers and burns that may host otters, and any faecal contamination from these animals is likely to be carried in the streams. However, typical population densities of coastal otters are low and therefore any impact is expected to be minor.

Other
Willdife sightings carried out in 2008 by Glenloy Wildlife (http://www.glenloy-wildlife.org.uk/id5.html Accessed 21/02/2012) recorded signs/and or sightings of Wild Boar (*Sus scrofa*) and Minke Whale (*Balaenoptera acutorostrata*), although numbers and species distribution were unavailable.

Two sightings of Northern Bottlenose Whale (*Hyperoodon ampullatus*) were made by the Hebridean Whale and Dolphin Trust in 2008 and 2009, on both occasions a single whale was observed (http://www.whaledolphintrust.co.uk/news_article.asp?news_id=130 Accessed 21/02/2012).

Conclusions
Wildlife species likely to contribute to background levels of contamination in Loch Eil are primarily gulls and deer, and potentially otters. While other species may be present in smaller numbers, they are not anticipated to have a significant impact on water quality in the area. Greatest impacts are likely to be at Garvan, where large numbers of gulls are regularly present, and then at Duisky, which lies nearby. There is also likely to be a large impact at The Narrows when gulls are nesting just to the east. Impacts from deer and otters are likely to be highest where watercourses empty into the loch.

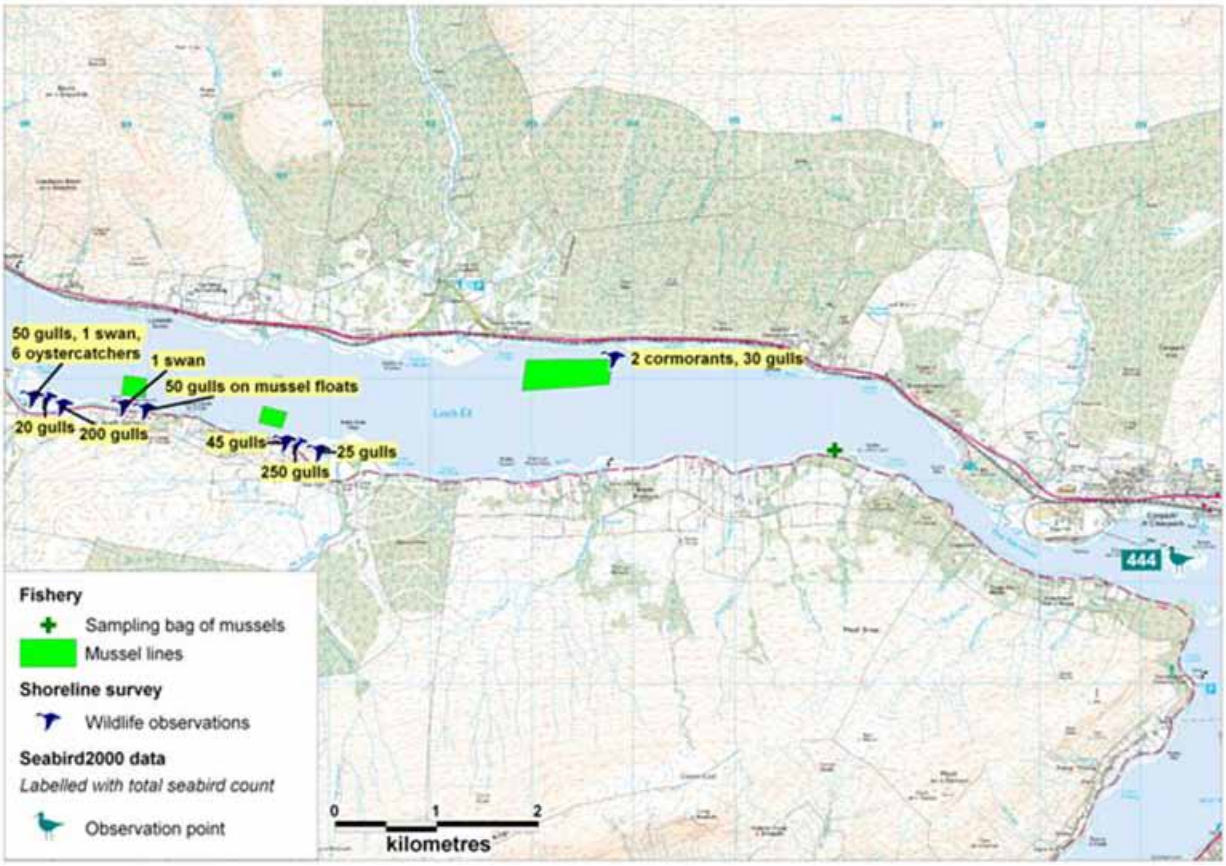


Figure 8.1 Map of seabird distributions for Loch Eil

9. Meteorological data

The nearest weather station is Conaglen House No 2, which is located approximately 10 km to the east of the production areas. Rainfall data was available for 2003-2009 with data missing from October, November and December of 2006. Data for 2010 was taken from Glen Nevis, which is situated 16 km south east of the fishery.

Wind data was available for Inverness, which is 90 km north of the fishery. Conditions may differ between this station and the fisheries due to the large distances between them. However the data is useful for identifying regional trends in wind patterns and, to a lesser extent, to rainfall patterns.

Data was purchased from the Meteorological Office and unless otherwise stated was used by Cefas for further analysis to formulate the content of this section (e.g. graphs). This section aims to describe the local rain and wind patterns in the context of the bacterial quality of shellfish at Loch Eil.

9.1 Rainfall

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

Figures 9.1 and 9.2 represent box and whisker plots that summarise the distribution of daily rainfall values by year and month respectivley. The grey box represents the middle 50% of the observations, with the median at the midline. The whiskers extend to the largest or smallest observations up to 1.5 times the box height above or below the box. Individual observations falling outside the box and whiskers are represented by the symbol *.

Figure 9.1 shows that 2006 and 2010 were drier than the other years. In Figure 9.2 a seasonal pattern is apparent with higher daily precipitation falling from September to January. April to July were the driest months. More extreme rainfall events (> 40mm) occurred throughout in all months but July, with higher peaks in rainfall occurring in the autumn and winter months. For the period considered here 42% of days experienced rainfall less than 1mm and 24% of days experienced rainfall of 10mm or more.

Taking the above into account, it would be expected that rainfall run-off would increase during the winter months causing a significant contribution to faecal contamination of the production area. However, it is likely that associated faecal contamination entering the production area will be greatest when extreme rainfall events occur during summer or early autumn after a build-up of faecal matter on pastures during the drier summer months when stock levels are at their highest.

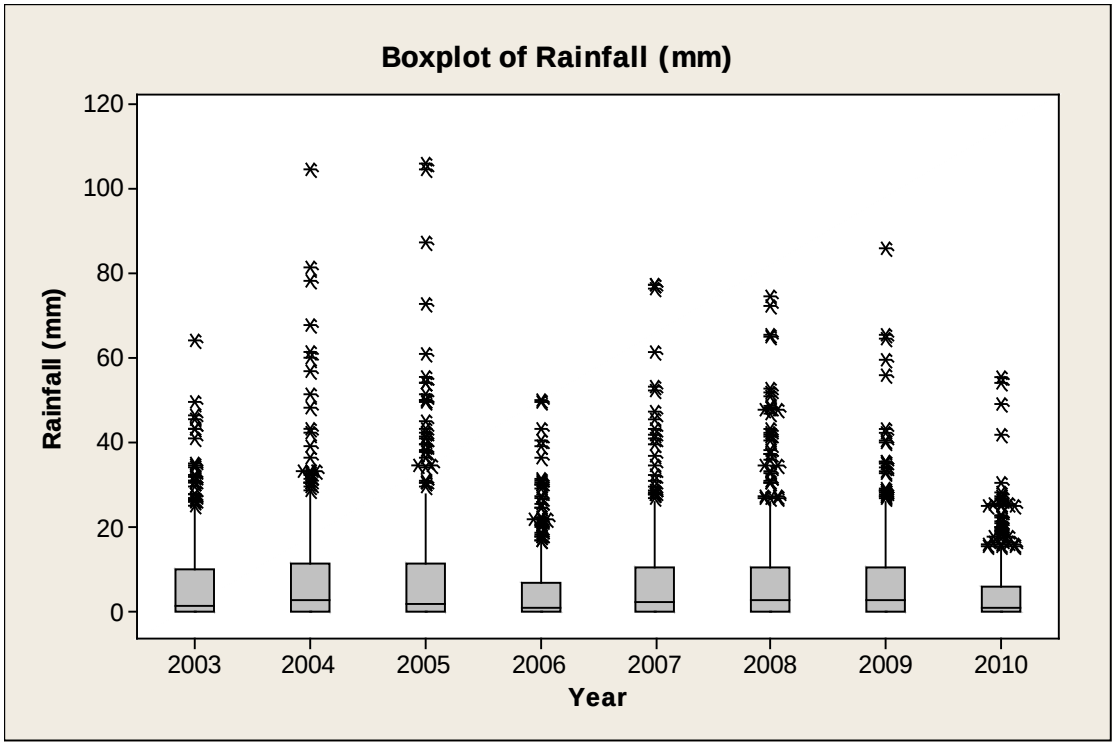


Figure 9.1 Box plot of daily rainfall values by year at Conaglen House No 2 (2003 – 2009) and Glen Nevis (2010)

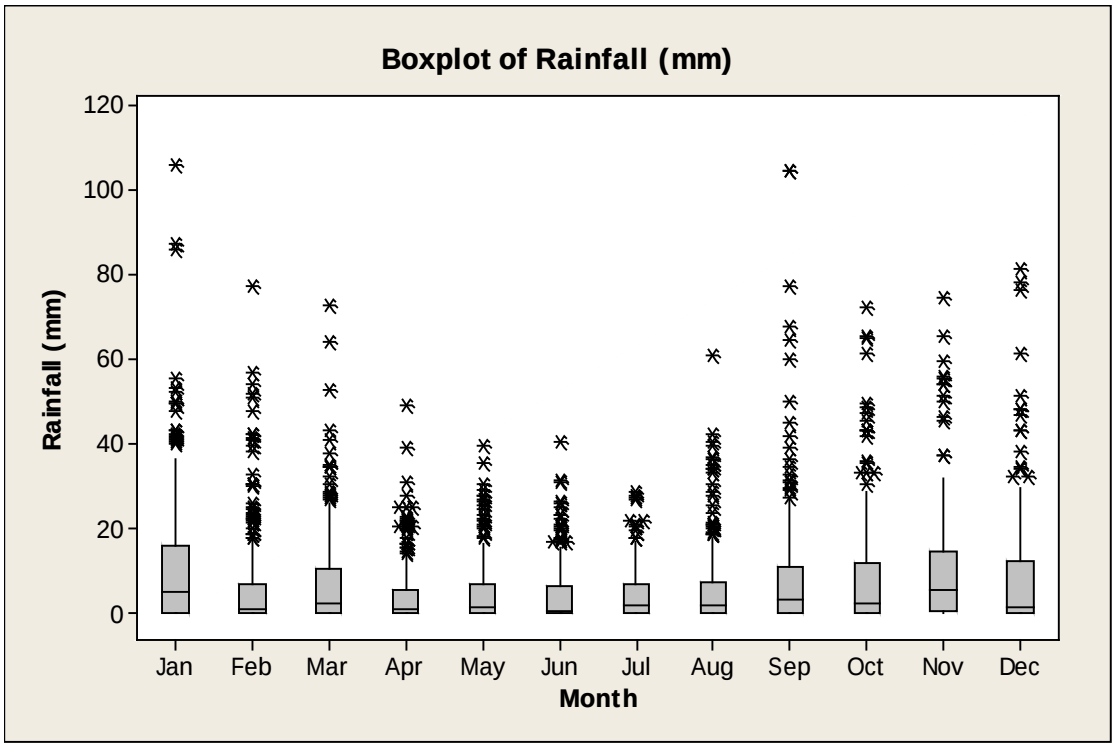


Figure 9.2 Box plot of daily rainfall values by month at Conaglen House No2 (2003 – 2009) and Glen Nevis (2010).

9.2 Wind

Wind data collected at Inverness is summarised by seasonal wind roses as shown in figure 9.3 and annually in figure 9.4.

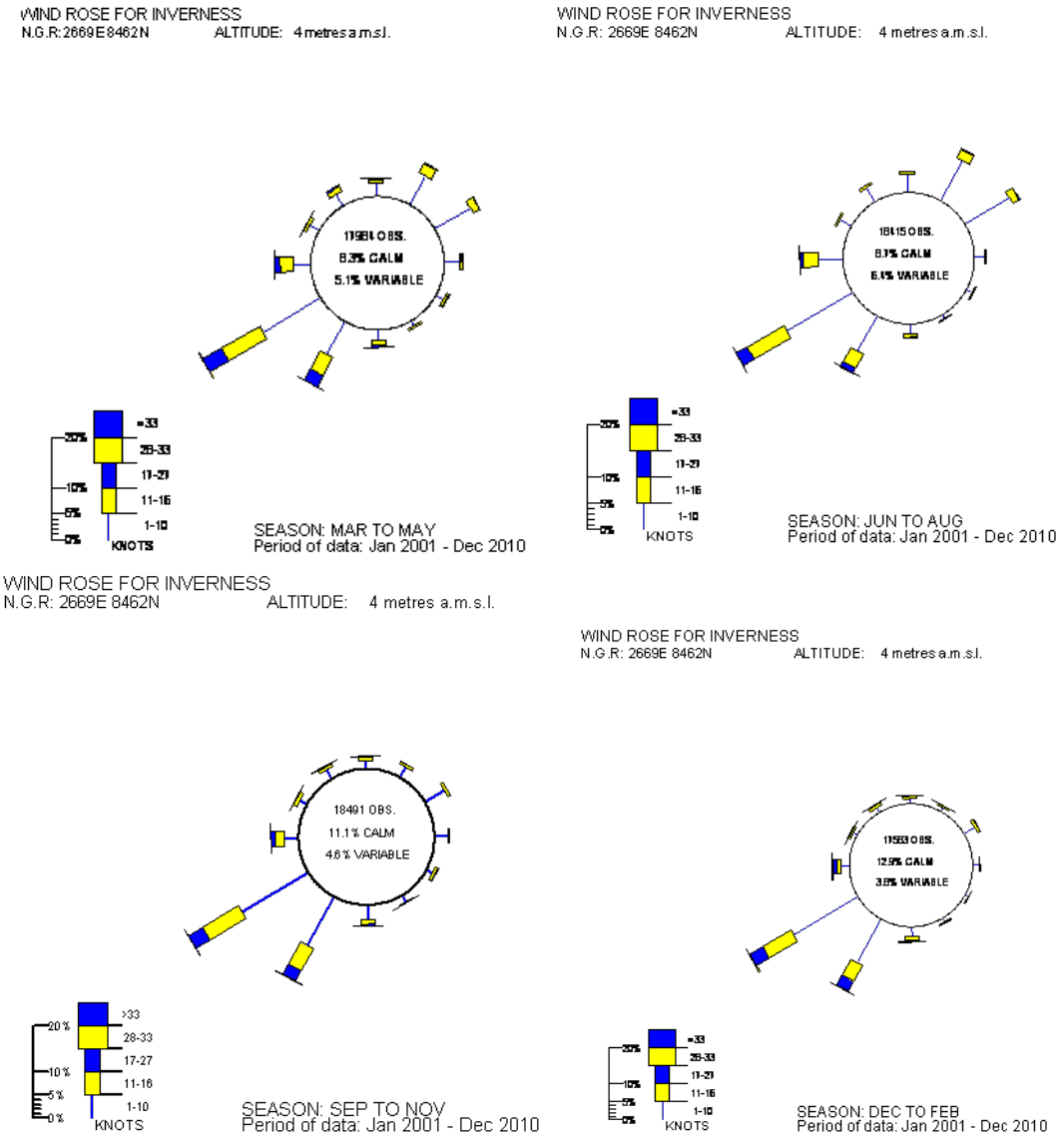


Figure reproduced under license from Meteorological Office. Crown Copyright 2012.

Figure 9.3 Seasonal wind roses for Inverness

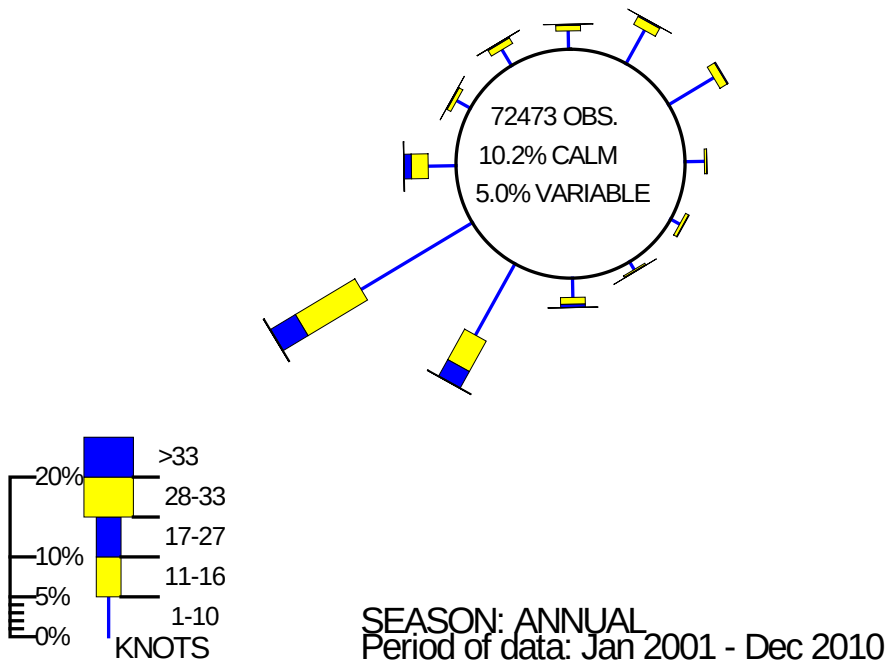


Figure 9.4 Annual wind rose for Inverness

The prevailing wind direction at Inverness is very strongly orientated from the south west; with similar patterns and strength of wind showing all year round, however the spring and summer months show a higher incidence of winds from the north east. Winds have the potential to contribute to the contamination of production areas as they are able 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 may significantly alter the surface movements at Loch Eil.

However, it should be noted that prevailing wind conditions at Loch Eil may differ from those reported at Inverness due to the distances between them. Due to local topography, winds at Loch Eil might be expected to follow a more east-west orientation as they are channelled by steep terrain along the axis of the loch.

Wind may affect tide height depending on wind direction and local hydrodynamics. A strong wind combined with a spring tide may result in higher than usual tides, which will carry accumulated faecal matter from livestock, in and above the normal high water mark, into the production area.

10. Current and historical classification status

All sites were classified for common mussels (*Mytilus edulis)*. The historical and current classifications for all three areas are shown in Tables 10.1 – 10.3.

Loch Eil (Duisky and Garvan)

Loch Eil was first given an overall provisional B classification in 2001 and full classification in 2002.

Table 10.1 Loch Eil (Duisky/ Garvan)

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
2001	b	b	b	b	b	b	b	b	b	b	b	b
2002	B	B	B	B	B	B	B	B	B	B	B	B
2003	A	A	A	A	B	B	B	B	A	A	A	A
2004	A	A	A	A	B	B	B	B	A	A	A	A
2005	B	B	B	B	B	B	B	B	B	B	B	B
2006	B	B	B	B	B	B	B	B	B	B	B	B
2007	B	B	B	B	B	B	B	B	B	B	B	B
2008	A	A	A	A	B	B	B	B	B	B	A	A
2009	A	A	A	B	B	B	B	B	B	B	B	B
2010	B	B	B	B	B	B	B	B	B	B	B	B
2011	B	B	B	A	A	B	B	B	B	B	B	B
2012	B	A	A									

Lower case denotes provisional classification

Loch Eil held year round B classifications for six years (2001, 2002, 2005, 2006, 2007 and 2010). Months that were classified A were more dominant in the winter – spring months, with no A classifications in the summer.

Loch Eil: Fassfern

Loch Eil: Fassfern was first classified in 2004.

Table 10.2 Loch Eil: Fassfern

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
2004						B	B	B	A	A	A	A
2005	B	B	B	B	B	B	B	B	A	A	A	A
2006	B	B	B	B	B	B	B	B	B	B	B	A
2007	B	B	B	A	B	B	B	B	B	B	B	A
2008	A	A	A	A	B	B	B	B	B	B	B	A
2009	A	A	A	B	B	B	B	B	B	B	A	A
2010	A	A	A	B	B	B	B	B	B	B	B	B
2011	B	B	B	B	B	B	B	B	B	B	B	B
2012	B	B	B									

Loch Eil: Fassfern held a year round classification of B for only one year (2011). In previous years, it held seasonal A/B classifications with A months tending to occur during the winter and early spring.

Loch Eil: Eil

Loch Eil: Eil was first classified in 2005.

Table 10.3 Loch Eil: Eil

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
2005	B	B	B	B	B	B	B	B	A	A	A	A
2006	A	A	A	B	B	B	B	B	B	B	B	B
2007	A	A	A	B	B	B	B	B	B	B	A	A
2008	A	A	A	B	B	B	B	B	B	B	B	A
2009	A	A	A	B	B	B	B	B	B	B	B	B
2010	A	A	A	B	B	B	B	B	B	B	B	B
2011	B	B	B	B	B	B	B	B	B	B	B	B
2012	B	B	B									

Loch Eil: Eil has held a mixed A/B classification with class B predominating. Class A classification was only seen in the autumn and winter months, with none in the summer months. This site has held B classification since April 2010.

Overall

The different production areas have all held seasonal A/B classifications historically, with A classifications tending to occur between September and March/April. However, both Loch Eil: Fassfern and Loch Eil: Eil have held year round B classifications since April 2010.

11. Historical *E. coli* data

11.1 Validation of historical data

Data for all mussel samples taken from Loch Eil, Loch Eil: Fassfern and Loch Eil: Eil production areas from the beginning of 2007 up to the end of 2011 were extracted from the database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data.

Loch Eil

One sample, dated 6/11/2007, was recorded as rejected by FSAS and was deleted from the data set. Three samples had results of <20 E. coli MPN/100g and these were assigned a value of 10 for statistical assessment and graphical presentation. No sample had a result of >18000 *E. coli* MPN/100 g.

Although all samples were recorded against the Garvan site on the FSAS database, all sampling locations that did not correspond to the position of the nominal RMP (which plots on land on the northern side of the loch) plotted in the vicinity of the Duisky site. The locations for two samples actually plotted 200 m to the east of the Loch Eil production area and within the Loch Eil: Fassfern production area. However, the locations plotted on the same side of the loch as the Loch Eil mussel lines and it was decided not to delete the samples from the data set (see Figure 11.1).

Sample receipt temperatures were all 8°C or below. None of the validated samples had been received at the laboratory more than 48 hours after collection. However, in one case, the lab received date/time was recorded as being before the collection date/time.

Loch Eil: Fassfern

One sample, dated 8/11/2007, was noted as rejected by FSAS and was deleted from the data set. No results were recorded as <20 or >18000 *E. coli* MPN/100 g. Sample receipt temperatures were all 8°C or below. None of the validated samples had been received at the laboratory more than 48 hours after collection.

All sampling locations plotted within the production area and either at the nominal RMP or in the vicinity of the present mussel lines.

Loch Eil: Eil

None of the samples were recorded as having been rejected by FSAS. Three samples had results of <20 E. coli MPN/100g and these were assigned a value of 10 for statistical assessment and graphical presentation. No sample had a result of >18000 *E. coli* MPN/100 g. Sample receipt temperatures were all 8°C or below. None of the validated samples had been received at the laboratory more than 48 hours after collection.

All sampling locations plotted within the previously defined boundaries for the production area.

11.2 Summary of microbiological results

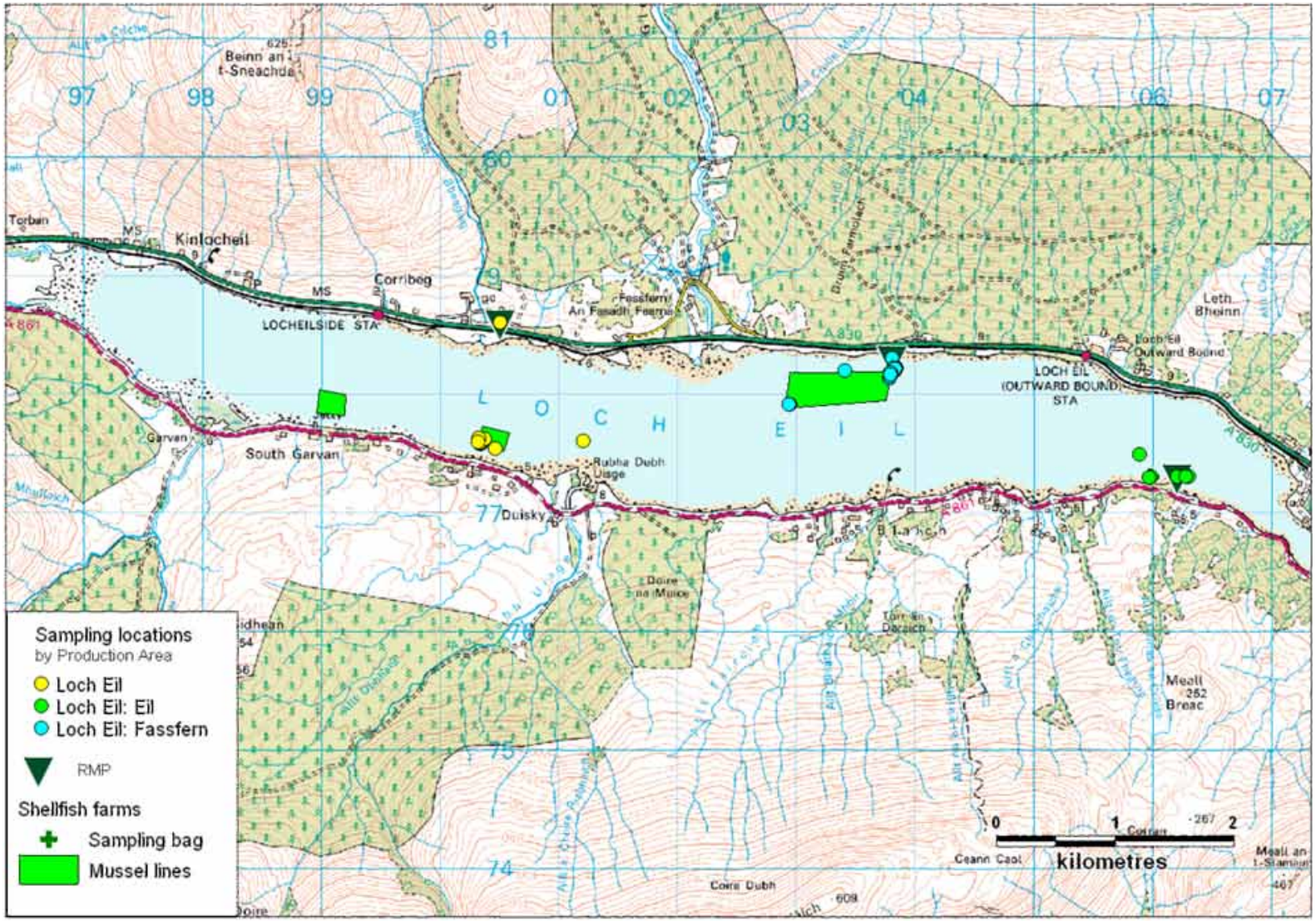
A summary of all sampling and results is presented in Table 11.1.

Table 11.1 Summary of historical sampling and results

Sampling Summary			
Production area	Loch Eil	Loch Eil: Fassfern	Loch Eil: Eil
Site	Duisky	Fassfern	Loch Eil
Species	Common Mussels	Common Mussels	Common Mussels
SIN	HL-134-217-08	HL-136-219-08	HL-135-218-08
Location	Various	Various	Various
Total no of samples	48	47	33
No. 2007	9	8	6
No. 2008	10	10	6
No. 2009	10	10	6
No. 2010	9	9	6
No. 2011	10	10	9
Results Summary			
Minimum	<20	20	<20
Maximum	9200	5400	9200
Median	245	460	500
Geometric mean	274	425	451
90 percentile	2400	2620	7680
95 percentile	6580	5400	9200
No. exceeding 230/100g	24 (50%)	29 (62%)	21 (64%)
No. exceeding 1000/100g	14 (29%)	16 (34%)	14 (42%)
No. exceeding 4600/100g	2 (4%)	3 (6%)	5 (15%)
No. exceeding 18000/100g	0 (0%)	0 (0%)	0 (0%)

11.3 Overall geographical pattern of results

For Loch Eil and Loch Eil: Fassfern, all sampling locations up to and including September 2008 were only recorded in the database to 100 m accuracy. For Loch Eil: Eil, the majority of sampling locations were recorded to this level of accuracy. For each production area, a significant proportion of samples had been recorded against the nominal RMP. The recorded sampling locations for the three production areas are shown in Figure 11.1.



Produced by Cefas Weymouth Laboratory.

Figure 11.1 Map of reported sampling locations

In the Loch Eil production area, the locations of 16 samples were recorded to 100 m accuracy, with 14 being recorded against the nominal RMP and 2 being recorded to a location 200 m to the east of the production area. As noted above, the nominal RMP plotted on land on the north side of the loch, whereas the farms in this production area lie on the southern side. Thirty-one of the 32 samples for which locations had been recorded to 10 m accuracy had been taken from the south-west corner of the lines at Duisky and the other sample had been recorded as being taken towards the middle of the southern side of the lines at Duisky. Therefore a geographical analysis of the results was not carried out. One of the highest results (9100 *E. coli* MPN/100g) had been recorded against the nominal RMP and the other (9200 *E. coli* MPN/100 g) was recorded as being taken at the south-western end of the lines.

In the Loch Eil, Fassfern production area, 15 of the samples locations had been recorded to 100 m accuracy. Thirteen of these were for samples recorded against the nominal RMP which lay on land at the north-eastern end of the current mussel lines. The two others had been recorded against a location 100 m to the west of that, but on the northern edge of the current mussel lines. Of the more recent samples where the locations had been recorded to 10 m accuracy, 29 were located in the vicinity of the north-eastern end of the present mussel lines, essentially as close as practical to the nominal RMP. Two samples were recorded as having been taken at the south-western end of the mussel lines. One of these had yielded the highest result of 5400 *E. coli* MPN/100 g. No formal geographical analysis of the results was undertaken due to the bias of sampling towards the north-eastern end of the lines.

In the Loch Eil: Eil production area, 28 of the samples were recorded as being taken on the eastern side of Rubha an t-Sionnaich and 5 on the western side. However, the former group included 24 samples that had been recorded against two locations given to 100 m accuracy, including the nominal RMP. Given doubts about the actual sampling location in many instances, and the small number of samples taken to the west of the promontory, a formal geographical analysis was not undertaken. The two highest results (both 9200 *E. coli* MPN/100 g) were assigned against a location recorded to 100 m accuracy and which plotted 100 m to the east of the nominal RMP.

The *E. coli* results for the three production areas were subjected to a one-way Analysis of Variance (ANOVA). There was no significant difference between the mean $\log_{10}$ transformed results for the three areas ($p=0.357$; Appendix 4). Boxplots of the results from the three production areas are shown in Figure 11.2.

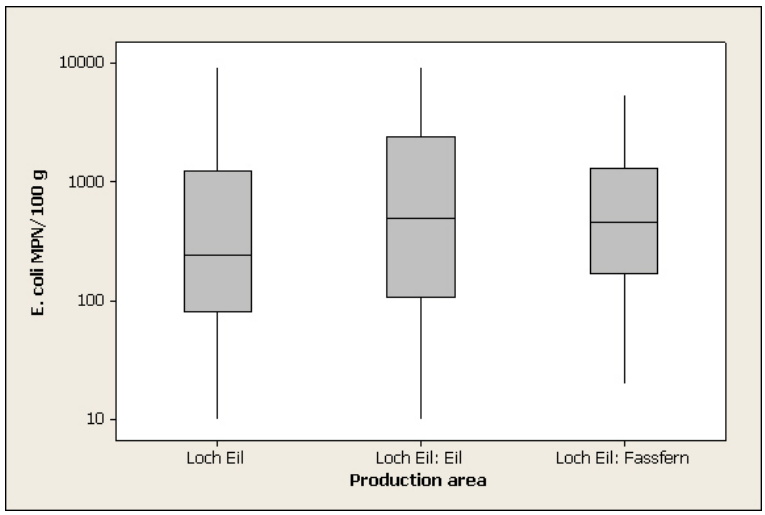


Figure 11.2 Boxplot of *E. coli* results by production area

11.4 Overall temporal pattern of results

Figure 11.3 presents a scatter plot of individual *E. coli* results against date, for each of the three production areas, fitted with loess smoother lines. Loess stands for 'locally weighted regression scatter plot smoothing'. At each point in the data set an estimated value is fit to a subset of the data, using weighted least squares. The approach gives more weight to points near to the x-value where the estimate is being made and less weight to points further away. In terms of the monitoring data, this means that any point on the loess line is influenced more by the data close to it (in time) and less by the data further away. The smoother line helps to highlight any apparent underlying trends or cycles.

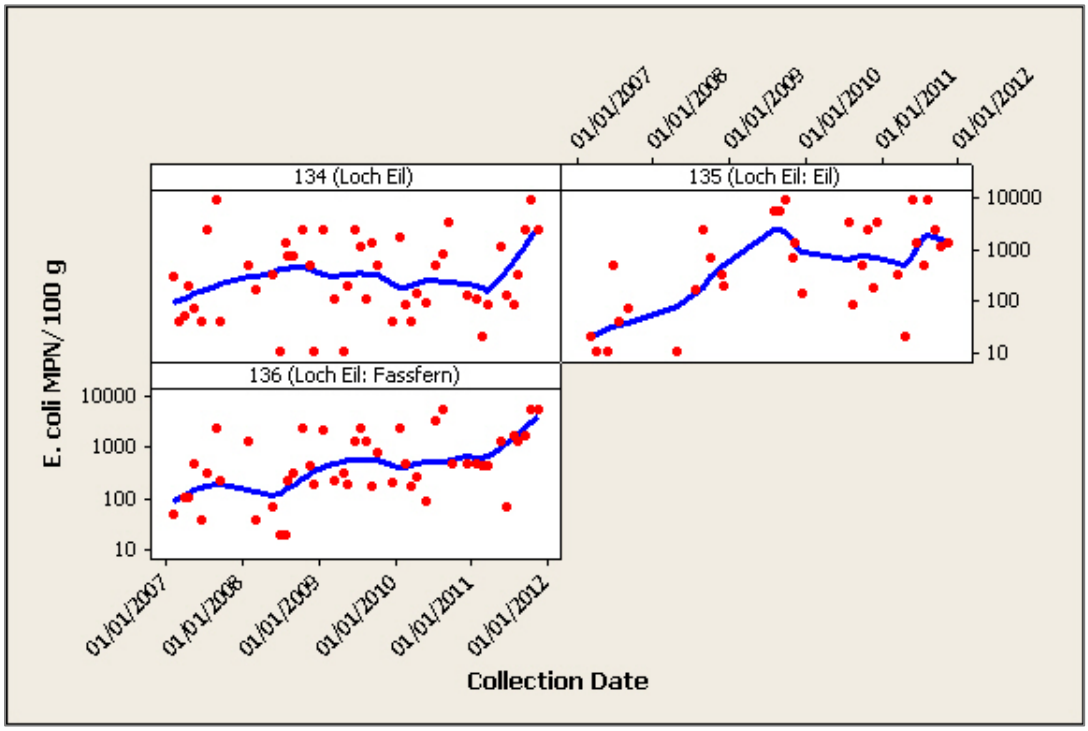


Figure 11.3 Loch Eil; Scatterplot of *E. coli* results by date for the three production areas

The plots suggest that there has been some increase in the general level of *E. coli* in mussels over time for all three production areas. Marked increases in results occured at all three areas during 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 of human occupation. All of these can affect levels of microbial contamination, and cause seasonal patterns in results. Figure 11.4 presents scatterplots of *E. coli* result by month for each of the three production areas, superimposed with loess smoother lines. In general, higher results were seen in the three production areas in summer and autumn, although high results were also seen in January at Loch Eil and Loch Eil: Fassfern. For the Loch Eil and Loch Eil: Fassfern production areas, there was a marked jump in results in July, which then decreased gradually toward December. At Loch Eil: Eil, the jump in results occurred in June.

For statistical evaluation, seasons were split into spring (March - May), summer (June - August), autumn (September - November) and winter (December - February). Boxplots of the results by season for each of the three areas is presented in Figure 11.5.

A two-way Analysis of Variance was undertaken of $\log_{10}$ *E.coli* against season and production area using General Linear Modelling. A significant difference was found between results by season (Two-way ANOVA, $p<0.001$). The interaction between season and production area was not significant ($p=0.54$) the seasonal effects were considered for the three production areas together.

A post ANOVA test (Tukey's comparison, Appendix 4) indicated that the results for spring were significantly lower than those of summer and autumn and that the results for winter were significantly lower than those of autumn.

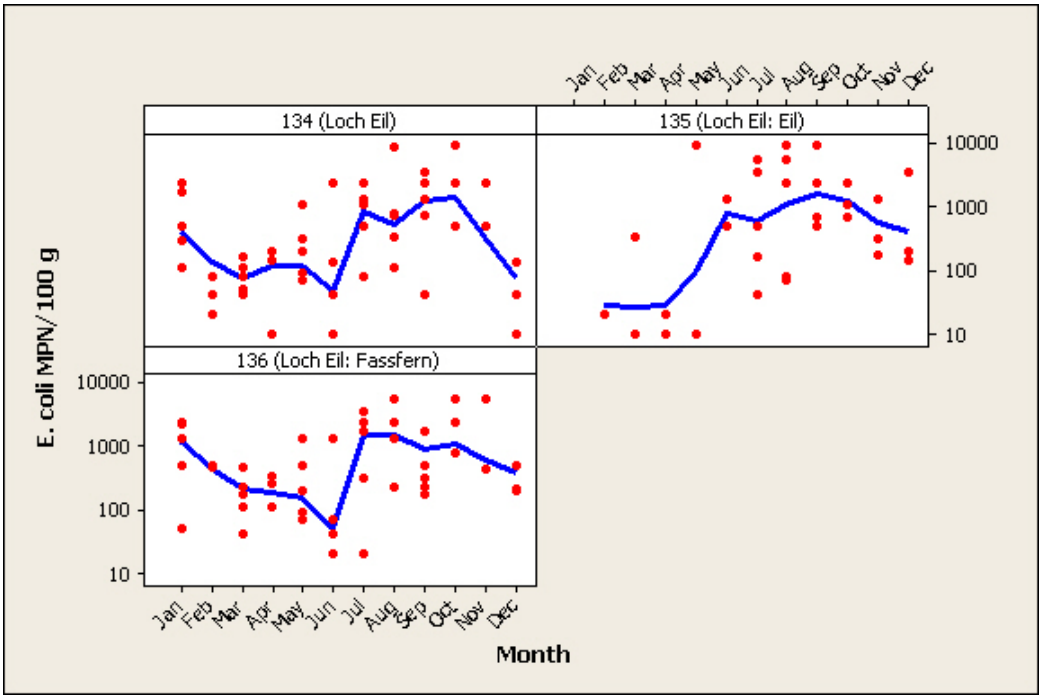


Figure 11.4 Loch Eil; Scatterplot of *E. coli* results by month for the three production areas

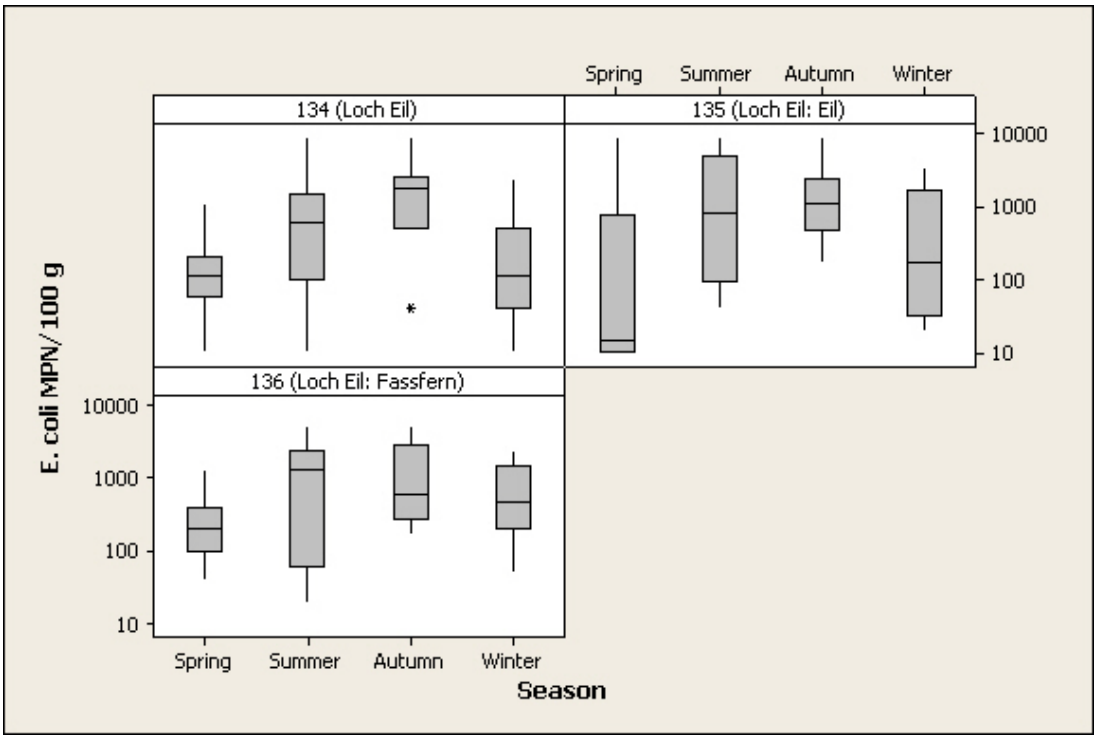


Figure 11.5 Loch Eil; Boxplot of *E. coli* results by season for the three production areas

11.6 Analysis of results against environmental factors

Environmental factors such as rainfall, tides, winds, sunshine and temperatures can all influence the flux of faecal contamination into growing

waters (e.g. Mallin *et al*, 2001; Lee & Morgan, 2003). The effects of these influences can be complex and difficult to interpret. This section aims to investigate and describe the influence of these factors individually (where appropriate environmental data is available) on the sample results using basic statistical techniques.

11.6.1 Analysis of results by recent rainfall

The nearest Meteorological Office weather station to Loch Eil is at Fort William, approximately 5 km from Loch Eil. However, only accumulated monthly data was available for this station and this was not appropriate for the present analyses. Glennfinnan No. 2 weather station is located approximately 7 km from Loch Eil but this was missing whole months of rainfall data several times each year. Conaglen House No. 2 weather station is located 8 km south of Loch Eil but no rainfall data was available after 1 April 2010. Ardgour, Clovullin weather station is located 14 km south of Loch Eil and a more complete data set was available for this: values were only missing for April 2007 and for one day in December 2010. Rainfall data was purchased from the Meteorological Office for the period up to 31/12/2010 (total daily rainfall in mm).

2-day antecedent rainfall

Figure 11.6 presents scatterplots for each of the three production areas of *E. coli* results against rainfall in the previous two days. A Spearman's Rank correlation was carried out between results and rainfall. A significant correlation was found between *E. coli* result and rainfall in the previous 2 days for Loch Eil: Fassfern and Loch Eil: Eil but not for Loch Eil (Loch Eil: Spearman's rank correlation=0.319, p=0.054; Loch Eil: Fassfern: Spearman's rank correlation=0.506, p=0.001; Loch Eil: Eil: Spearman's rank correlation=0.551, p=0.005). The scatterplots show that the main effect at Loch Eil: Fassfern and Loch Eil: Eil is that very low results tend not to be seen after moderate amounts of rainfall over the previous two days (10 mm or less).

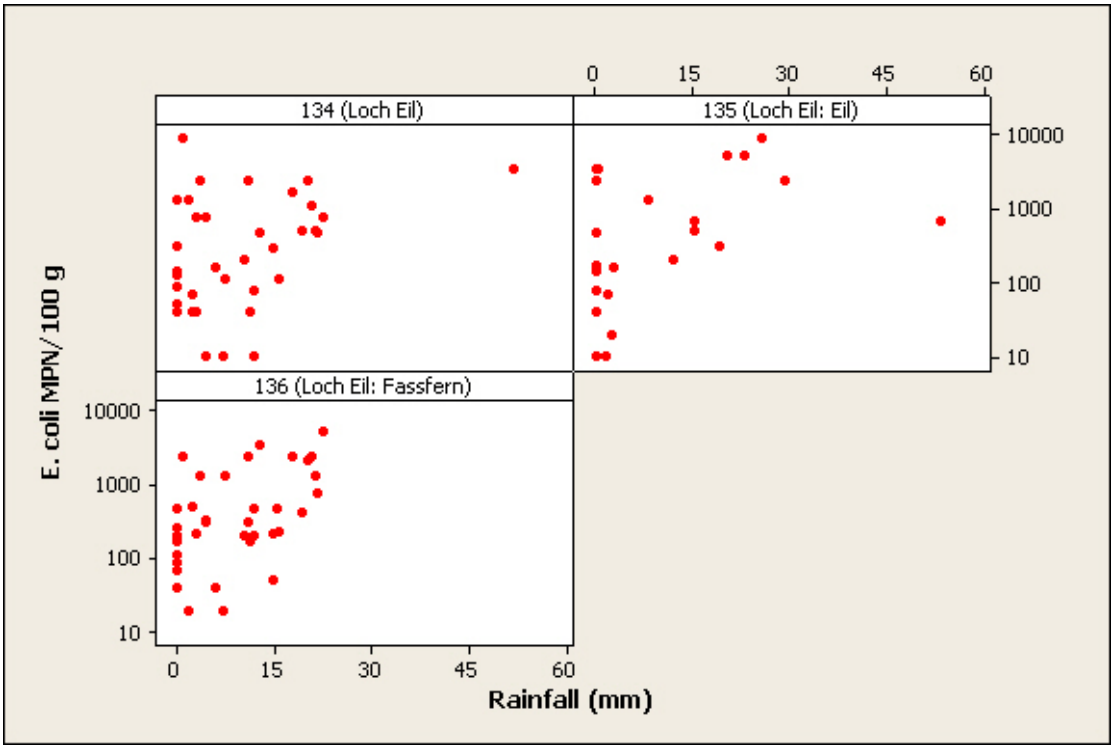


Figure 11.6 Scatterplot of result against rainfall in previous 2 days

7-day antecedent rainfall

As the effects of heavy rain may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationship between rainfall in the previous 7 days and sample results was investigated in an identical manner to the above.

Scatterplots of *E. coli* results against rainfall in the previous 7 days are presented in Figure 11.7 for each of the three production areas. A significant positive correlation was found between *E. coli* result and rainfall in the previous 7 days for Loch Eil but not for Loch Eil: Fassfern or Loch Eil: Eil although the probabilities for the latter were borderline at the 5% level (Loch Eil: Spearman's rank correlation=0.409, p=0.012; Loch Eil: Fassfern: Spearman's rank correlation=0.325, p=0.050; Loch Eil: Eil: Spearman's rank correlation=0.399, p=0.053).

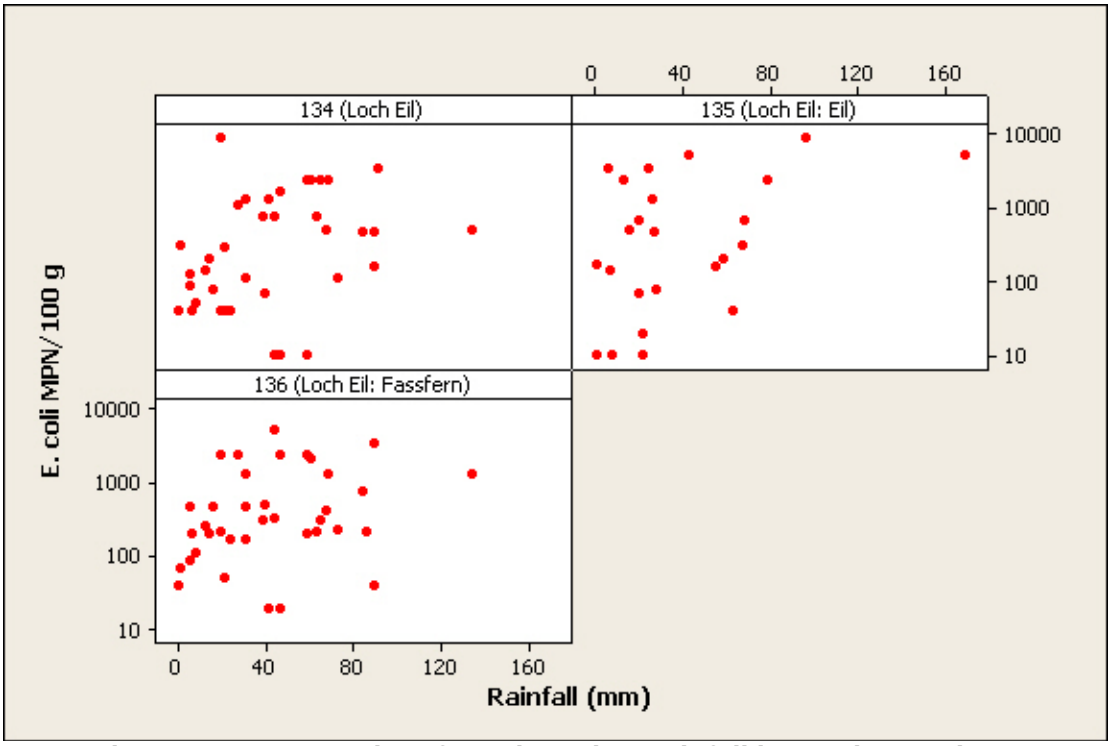


Figure 11.7 Scatterplot of result against rainfall in previous 7 days

11.6.2 Analysis of results by tidal height and state

Spring/neap tidal cycle

When the larger (spring) tides occur every two weeks, circulation of water and particle transport distances will increase, and more of the shoreline will be covered at high water, potentially washing more faecal contamination from livestock into the area. Figures 11.8, 11.9 and 11.10 present polar plots of $\log_{10}$ *E. coli* results for the three production areas in relation to the lunar spring/neap tidal cycle. Full/new moons are located at 0º, and half moons at 180º. The largest (spring) tides occur about 2 days after the full/new moon, located at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. It should be noted that local meteorological conditions such as wind strength and direction can influence the height of tides and this is not taken into account.

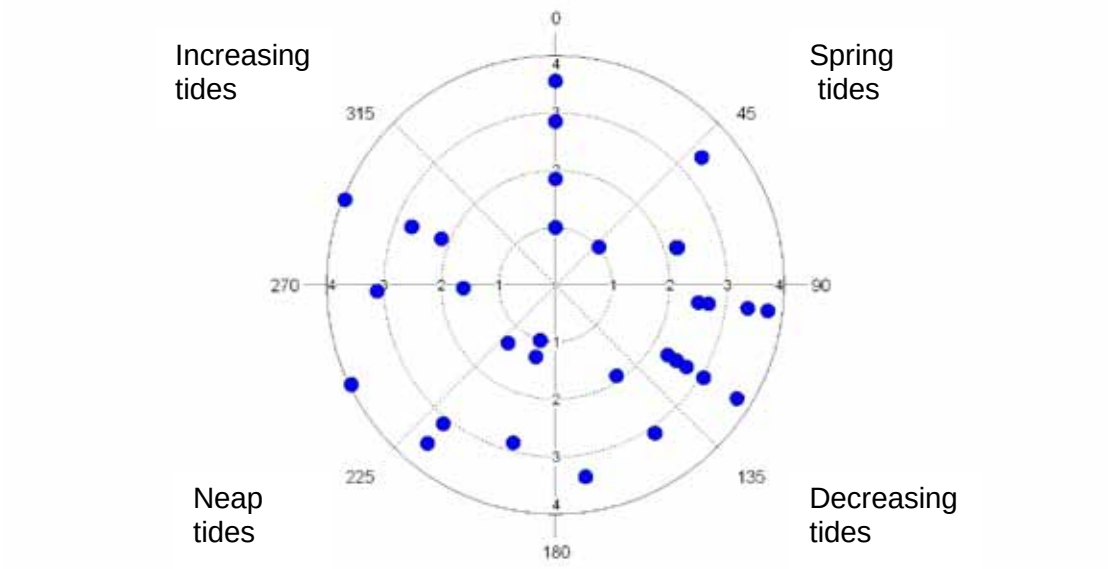


Figure 11.8 Polar plot of log_{10} *E. coli* results at Loch Eil on the spring/neap tidal cycle

No significant correlation was found between log_{10} *E. coli* results and the spring/neap cycle at the Loch Eil production area (circular-linear correlation, r=0.036, p=0.944).

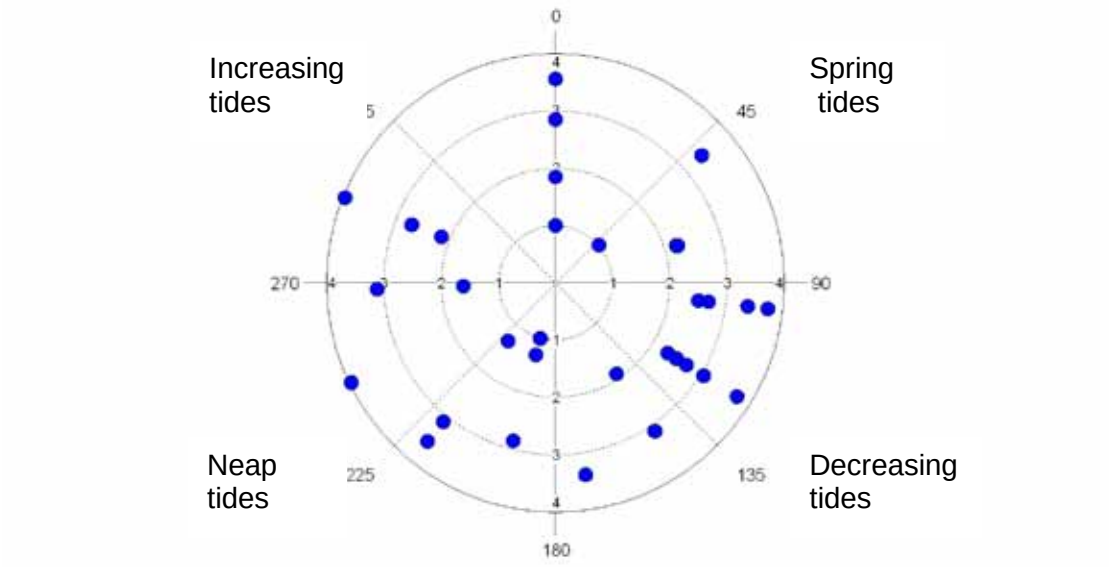


Figure 11.9 Polar plot of log_{10} *E. coli* results at Loch Eil: Eil on the spring/neap tidal cycle

No significant correlation was found between log_{10} *E. coli* results and the spring/neap cycle at Loch Eil: Eil production area (circular-linear correlation, r=0.090, p=0.785).

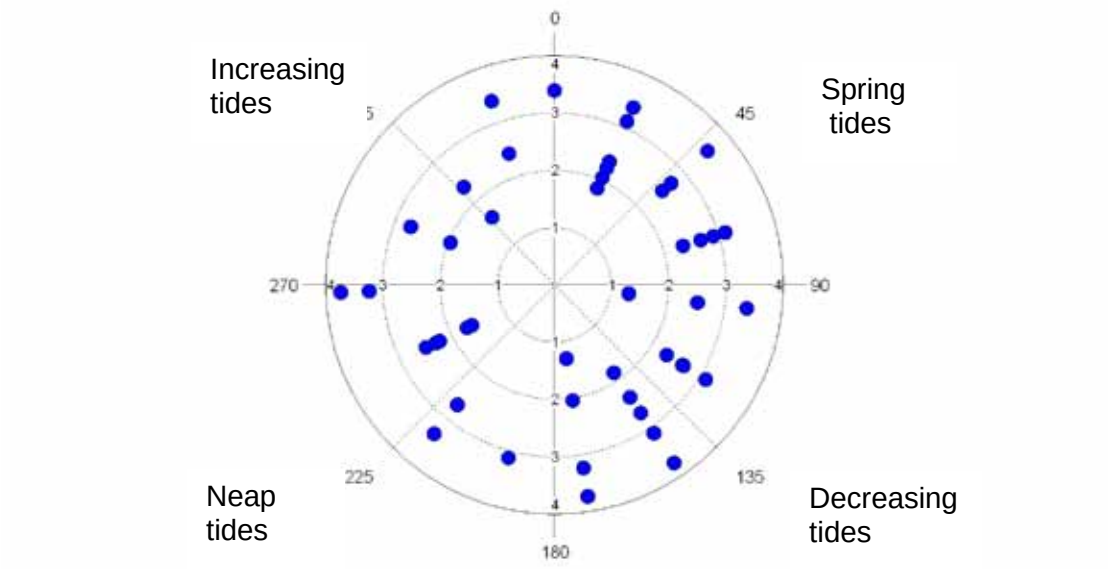


Figure 11.10 Polar plot of log_{10} *E. coli* results at Loch Eil:Fassfern on the spring/neap tidal cycle

No significant correlation was found between log_{10} *E. coli* results and the spring/neap cycle at Loch Eil: Fassfern (circular-linear correlation, r=0.102, p=0.631).

High/low tidal cycle

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the farms during this cycle. As *E. coli* levels in some shellfish species can respond within a few hours or less to changes in *E. coli* levels in water, tidal state at time of sampling (hours post high water) was compared with *E. coli* results. Figures 11.11, 11.12 and 11.13 present polar plots of log_{10} *E. coli* results on the lunar high/low tidal cycle for the three production areas. High water is located at 0º, and low water at 180º.

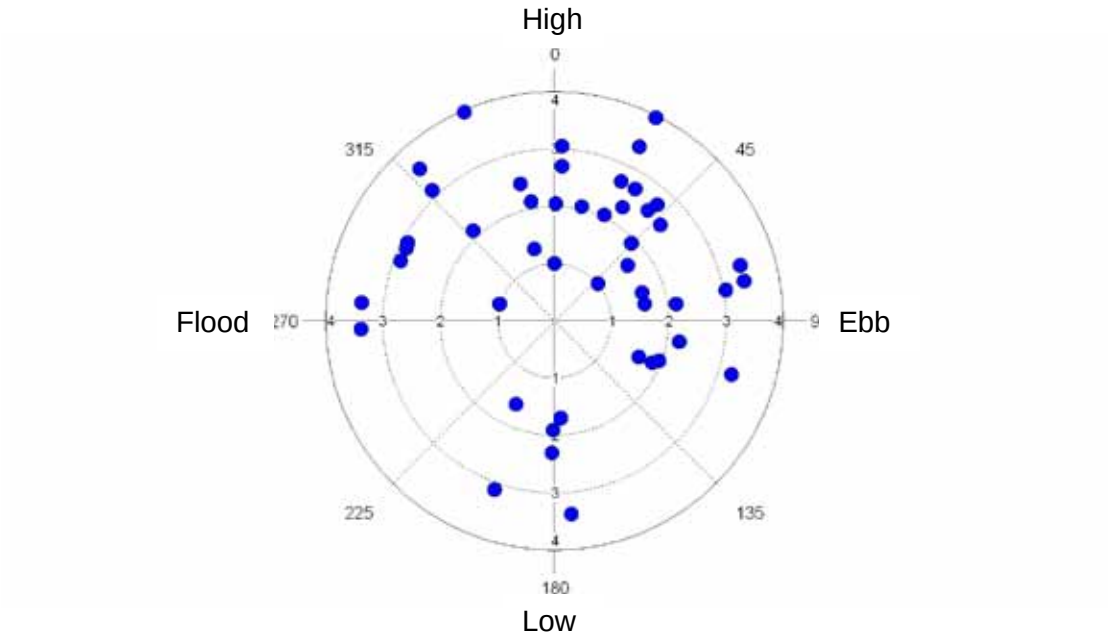


Figure 11.11 Polar plot of $\log_{10}$ *E. coli* results at Loch Eil on the high/low tidal cycle

No significant correlation was found at the Loch Eil production area between *E. coli* results and the high/low tidal cycle (circular-linear correlation, r=0.202, p=0.159). However, most samples had been taken on the second half of the flood tide, at high water and on the first half of the ebb tide.

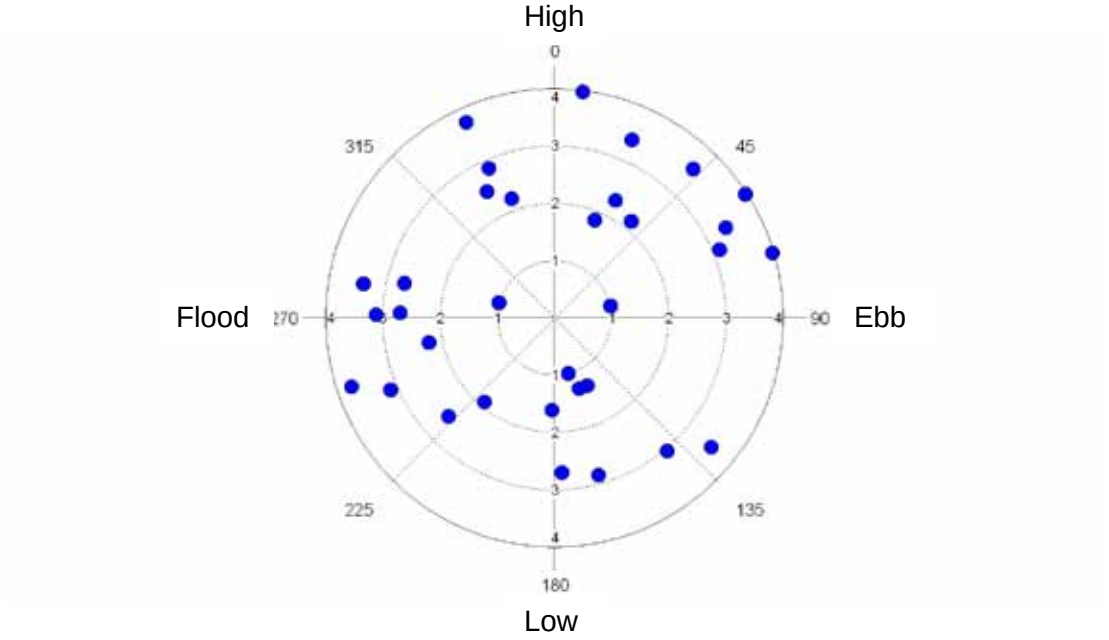


Figure 11.12 Polar plot of $\log_{10}$ *E. coli* results at Loch Eil: Eil on the high/low tidal cycle

A weak but significant correlation was found at Loch Eil: Eil between *E. coli* results and the high/low tidal cycle (circular-linear correlation, r=0.334, p=0.035). The highest results were seen shortly after high tide and during the first half of the ebb tide.

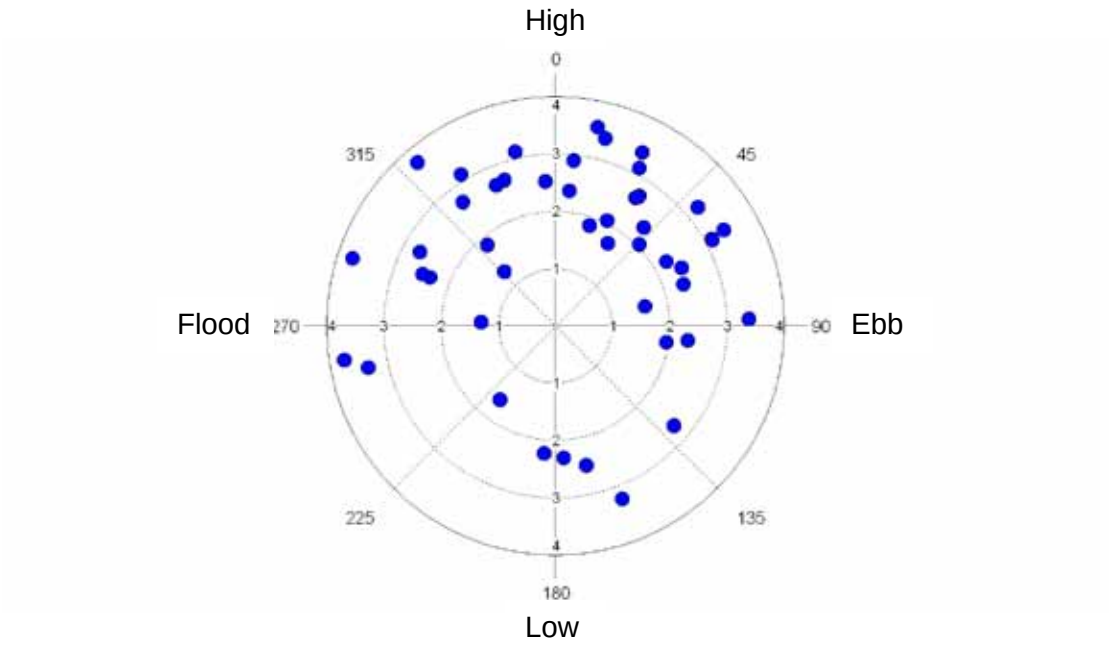


Figure 11.13 Polar plot of log_{10} *E. coli* results at Loch Eil: Fassfern on the high/low tidal cycle

No significant correlation was found at Loch Eil: Fassfern between *E. coli* results and the high/low tidal cycle (circular-linear correlation, r=0.117, p=0.550). Most samples had been taken on the second half of the flood tide, at high water and on the first half of the ebb tide.

11.6.3 Analysis of results by water temperature

Water temperature is likely to affect the survival time of bacteria in seawater (Burkhardt *et al*, 2000) and the feeding and elimination rates of shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. It is of course closely related to season, and so any correlation between temperatures and *E. coli* levels in shellfish flesh may not be directly attributable to temperature, but to other factors such as seasonal differences in livestock grazing patterns. Figure 11.14 presents scatterplots of *E. coli* results against water temperature for the three production areas.

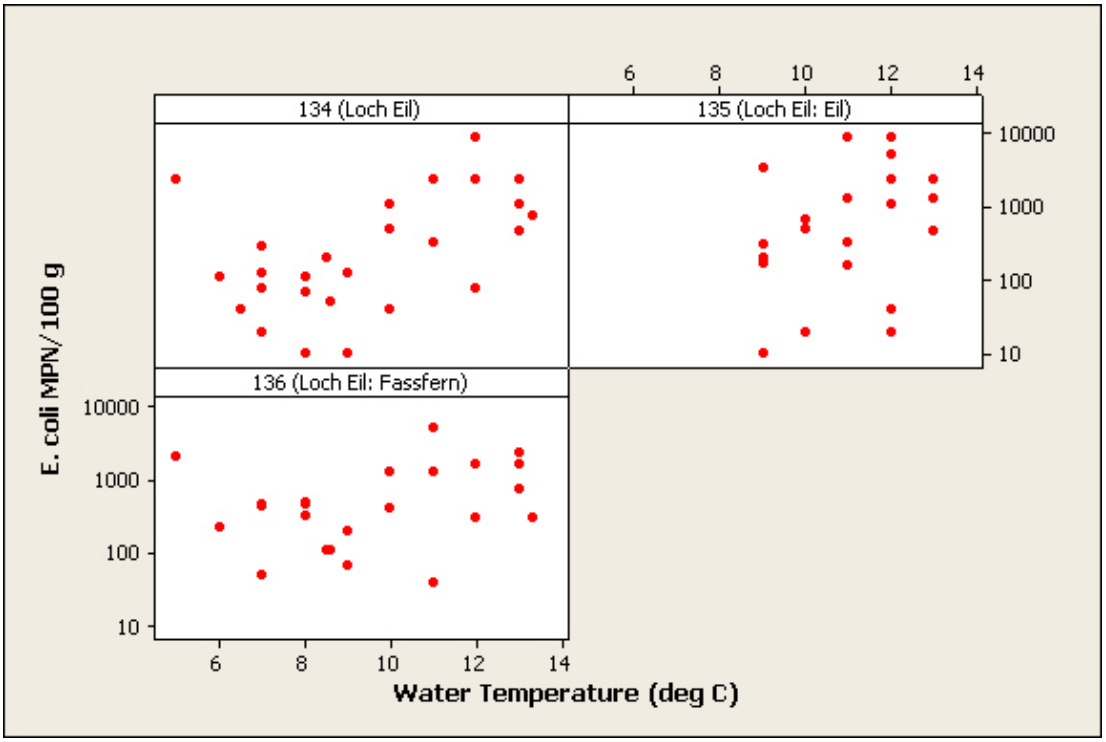


Figure 11.14 Scatterplot of result by water temperature

Water temperature was recorded for 74 of the 128 samples across the three production areas. The recorded water temperatures ranged from 5.0°C to 13.5°C. A significant correlation was seen between *E. coli* results and water temperature at Loch Eil (Spearman's rank correlation= 0.511, p=0.006) but not at Loch Eil: Eil (Spearman's rank correlation= 0.349, p=0.121) or Loch Eil: Fassfern (Spearman's rank correlation= 0.302, p=0.134). The trend for Loch Eil is distinct in Figure 11.14 with only one high result being seen at a low seawater temperature.

11.6.4 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence, and hence freshwater borne contamination at the site. Salinity was recorded for 90 of the 128 samples across the three production areas. The recorded salinity values ranged from 8 ppt to 34 ppt. Values less than 20 ppt were seen in all three production areas, indicating significant freshwater influence. Figure 11.15 presents scatter plots of *E. coli* result against salinity for the three production areas. No significant correlation was found between the *E. coli* result and salinity for any of the production areas (Spearman's rank correlation; Loch Eil r=-0.174, p=0.304; Loch Eil: Eil r=-0.181, p=0.488; Loch Eil: Fassfern r=--0.206, p=0.228).

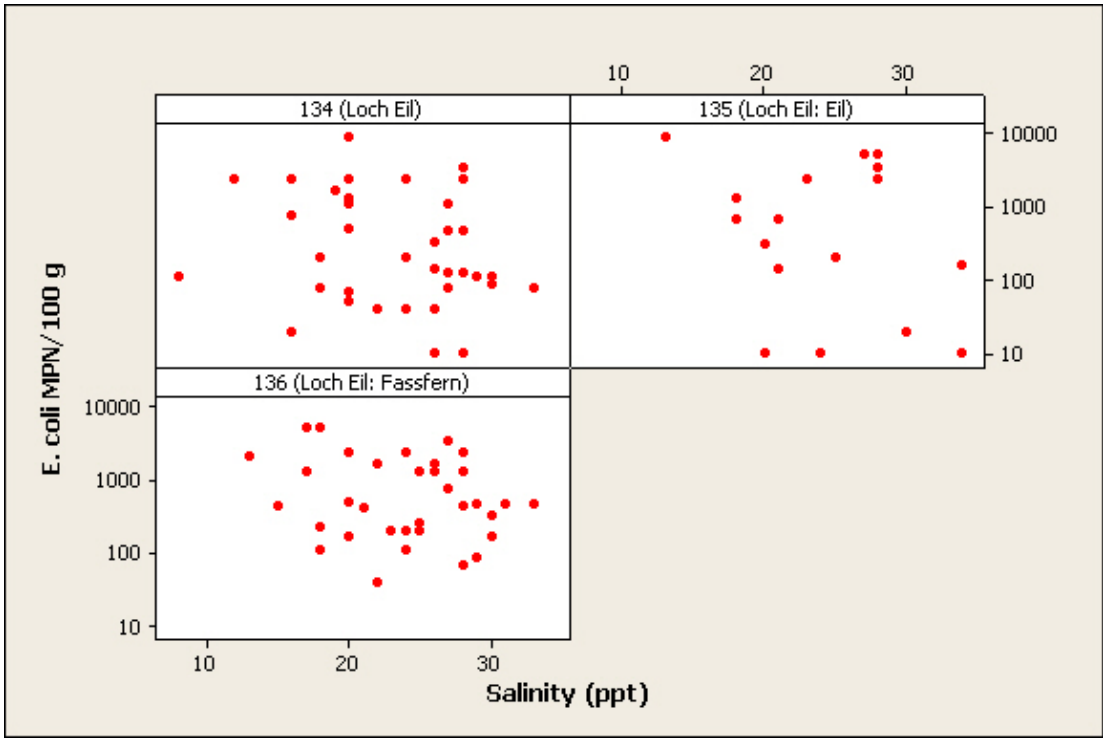


Figure 11.15 Scatterplot of result by salinity

11.7 Evaluation of results over 4600 *E. coli* MPN/100g

A total of 10 samples gave a result of over 4600 *E. coli* MPN/100 g, details of which are presented in Table 11.2.

The greatest number of results exceeding 4600 *E. coli* MPN/100 g was seen at Loch Eil: Eil despite this area having fewer samples over the period than the other two production areas. Apart from one sample taken in 2007, all had been taken from July 2009 onwards. All of the high results were seen between May and November. Significant levels of rainfall had occurred in the 2 days prior to sampling in 4 of the 5 cases for which data was available. For the 6 samples where water temperature data was available, the recorded values were either 11 or 12°C. For the 7 samples for which salinities were available, the recorded values ranged from 13 to 28 ppt. There did not appear to be a pattern with respect to the spring/neap tidal cycles. With the high/low tidal cycle, the three highest results at Loch Eil: Eil had been taken over the period from just after high tide and on the first half of ebb tide. At Loch Eil: Fassfern, the three samples had been taken on the flood tide.

Table 11.2 Historic *E. coli* sampling results over 4600 *E. coli* MPN/100 g

Collection date	*E. coli* (MPN/100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tidal state (high/ low)	Tidal state (spring/ neap)
Loch Eil								
29/08/2007	9100	NN 005 786	1.1	19.6	*	*	Ebb	Spring
18/10/2011	9200	NN 0031 7760	*	*	12	20	Flood	Decreasing
Loch Eil: Eil								
27/07/2009	5400	NN 062 773	23.1	42.8	*	28	Flood	Decreasing
24/08/2009	5400	NN 063 773	20.2	169.1	12	27	Flood	Decreasing
28/09/2009	9200	NN 063 773	25.7	96.3	*	13	Ebb	Neap
29/05/2011	9200	NN 063 773	*	*	12	*	High	Increasing
09/08/2011	9200	NN 0627 7730	*	*	11	*	Ebb	Neap
Loch Eil: Fassfern								
17/08/2010	5400	NN 02937 77911	22.5	43.9	*	17	Flood	Decreasing
18/10/2011	5400	NN 03787 78176	*	*	11	18	Flood	Decreasing
21/11/2011	5400	NN 03788 78166	*	*	11	18	Flood	Increasing

* Data unavailable

11.8 Summary and conclusions

Although the Loch Eil: Eil and Loch Eil: Fassfern production areas showed higher average levels of contamination than the Loch Eil production area, the difference was not statistically significant. The Loch Eil: Eil production area yielded a much higher proportion of samples greater than 4600 *E. coli* per 100g than did the other two production areas (15% against 4 and 6%). The Loch Eil: Eil production area is situated near the narrows at the mouth of the loch whereas the other two production areas are situated within the body of the loch.

The time trend graphs showed that there appears to have been some increase in *E. coli* results over the period in all three production areas and all but one of the results greater than 4600 *E. coli*/ 100g occurred from July 2009 onward. Highest results were seen in summer and autumn and results greater than 4600 *E. coli*/100 g were only seen from May to November. A significant correlation was seen between *E. coli* results and water temperature at Loch Eil but not at the other two production areas. A summary of correlations

observed between environmental factors and E. coli monitoring results is presented in Table 11.3, along with an indicator of where they lie geographically in relation to one another on a west to east axis.

Table 11.3 Summary of monitoring results and environmental factors

West → East			
Parameter	**Loch Eil**	**Loch Eil: Fassfern**	**Loch Eil: Eil**
Season	summer/autumn	summer/autumn	summer/autumn
2-day rain	none	+	+
7-day rain	+	none	none
Water temperature	+	none	none
Salinity	none	none	none
Spring/Neap tide	none	none	none
High/Low tide	none	none	+ (weak)

A significant correlation was found between *E. coli* result and rainfall in the previous 2 days for Loch Eil: Fassfern and Loch Eil: Eil but not for Loch Eil. A significant positive correlation was found between *E. coli* result and rainfall in the previous 7 days for Loch Eil but not for Loch Eil: Fassfern or Loch Eil: Eil. Where data was available, results greater than 46000 *E. coli*/100 g tended to occur after significant levels of rain (20 mm or more) in the 2 days prior to sampling. However, no significant correlation was found between the *E. coli* result and salinity for any of the production areas. Therefore, while the loch is significantly impacted by freshwater, the relationship between rainfall-related inputs and the *E. coli* results seen in the mussels is complex.

No significant correlations were found between *E. coli* results and the spring/neap tidal cycle at any of the production areas. A weak but significant correlation was found at Loch Eil: Eil between *E. coli* results and the high/low tidal cycle: the highest results of 9200 *E. coli*/100 g were seen from just after high tide and during the first half of the ebb tide. At Loch Eil: Fassfern, the three highest results were seen on the flood tide which would imply a source to the east of the sampling locations.

The relatively small amount of data precluded the assessment of the effect of interactions between environmental factors on the *E. coli* concentrations in shellfish.

11.9 Sampling frequency

When a production area holds a non-seasonal classification, and where at least 24 results are available over the past 3 years, and the geometric mean of those results falls within a certain range, consideration can be given to reducing the sampling frequency from monthly to bimonthly.

The classification of the Loch Eil production area is currently a seasonal A/B and so this area was not investigated further.

Both Loch Eil: Eil and Loch Eil: Fassfern currently hold year-round B classifications. At Loch Eil: Eil, 27 samples had been taken over the 3 year period from October 2008 to September 2011. The geometric mean of the results was 783 *E. coli*/100 g. At Loch Eil: Fassfern, 39 samples had been taken over the same period and the geometric mean of the results was 499 *E. coli*/100 g. Both of the geometric mean values are greater than the upper class B stability limit of 210 given in the EURL Good Practice Guide and so it is not recommended that the sampling frequency be reduced.

12. Designated Shellfish Growing Waters Data

The Loch Eil: Fassfern and Loch Eil: Eil production areas fall within the Loch Eil designated shellfish growing water. The area was designated in 2005 and a full monitoring regime implemented in the second half of 2005. SEPA is responsible for ensuring that monitoring is undertaken for a variety of parameters, including faecal coliforms in shore mussels. The sampling point used by SEPA for SGW monitoring at Loch Eil is NN 03030 77024. The relative positions of the SGW boundaries, mussel farms and SGW monitoring point are shown in Figure 12.1.

Since 2007, SEPA have obtained shellfish classification monitoring results (*E. coli*) under an agreement with FSAS for the purposes of SGW monitoring. Those results have been used in the analysis in Section 11 of this report and so are not repeated here.

Table 12.1 SEPA monitoring results for shore mussels - Loch Roag

Year	Quarter	Faecal coliform results (FC/100g)
2005	Q1	-
	Q2	-
	Q3	750
	Q4	3900
2006	Q1	310
	Q2	750
	Q3	-
	Q4	4300
2007	Q1	17000
	Q2	-
	Q3	-
	Q4	-

- No result reported

Results of monitoring from Q3 2005 through Q1 2007 were available. Results in Q4 for both 2005 and 2006 were over 1000 FC/100 g and the result in Q1 of 2007 was well in excess of 4600 FC/100 g. Insufficient sampling was undertaken to enable further analysis of these results.

Although levels of faecal coliforms are usually correlated to levels of *E. coli* at a ratio of roughly 1:1, the ratio depends on a number of factors, such as environmental conditions and the source of contamination. Comparison is further complicated by differences in accumulation between the different species of shellfish. Consequentially, the results presented in Table 12.1 are not directly comparable with the other shellfish testing results presented in this report.

Overall, the results indicate that the area is subject to significant levels of faecal contamination.

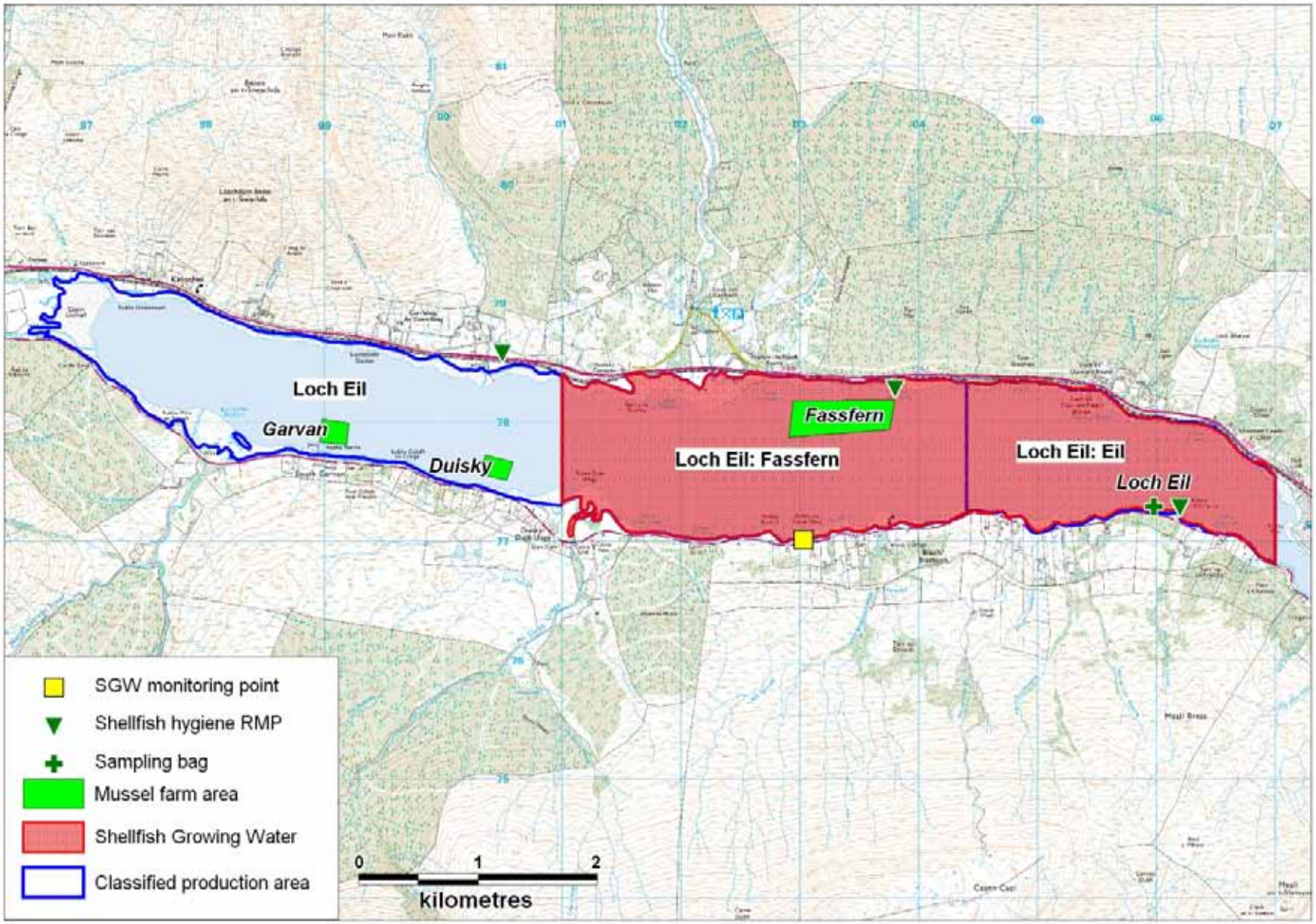


Figure 12.1 Designated shellfish growing water – Loch Eil

13. River Flow

There are no river gauging stations on rivers or burns within Loch Eil. The rivers and streams listed in Table 13.1 were measured and sampled during the shoreline survey. These represent the freshwater inputs to the loch in the vicinity of the three shellfisheries and at the head of the loch. There was light rain during the first part of the shoreline survey and heavy rain during the second half. The locations, together with the calculated loadings, are shown in Figure 13.2.

Table 13.1 River (or stream) loadings for Loch Eil

No	Grid Ref	Description	Width (m)	Depth (m)	Flow (m/s)	Flow in m^3/day	*E.coli* (cfu/ 100ml)	Loading (*E.coli* per day)
1	NM 95930 79133	Fionn Lighe	19.1	0.475	0.151	121251	<100	$<1.2 \times 10^{11}$
2	NM 96156 78789	Dubh Lighe	10.3	0.375	0.262	213541	<100	$<2.1 \times 10^{11}$
3	NN 01102 76993	Duisky River	3.7	0.5	0.342	54665	<100	$<5.5 \times 10^{10}$
4	NN 00935 77219	Alt Dubhaig	4.2	0.18	0.176	11496	200	2.3×10^{10}
5	NN 00562 77368	Small piped stream	0.5	0.09	0.04	156	300	4.7×10^{8}
6	NN 00384 77435	Very small stream	0.19	0.02	0.299	98	<100	$<9.8 \times 10^{7}$
7	NN 00209 77448	Very small stream	0.25	0.09	0.022	43	<100	$<4.3 \times 10^{7}$
8	NM 99789 77589	Stream	0.43	0.08	0.015	45	<100	$<4.5 \times 10^{7}$
9	NM 99186 77684	Stream	0.9	0.07	0.14	762	<100	$<7.6 \times 10^{8}$
10	NM 98998 77705	Small stream	0.65	0.09	0.1	505	<100	$<5.1 \times 10^{8}$
11	NM 98802 77727	Stream	0.95	0.08	0.039	256	<100	$<2.6 \times 10^{8}$
12	NM 97964 77742	Garvan River	11.8	0.33	0.354	119794	<100	$<1.2 \times 10^{11}$
13	NN 06329 77103	Alt Camas na Croise	1.85	0.35	2.087	116755	3100	3.6×10^{12}
14	NN 06230 77156	Small stream	0.42	0.13	0.903	4260	2500	1.1×10^{11}
15	NN 05975 77225	Small piped stream	0.3	0.04	0.985	1021	1500	1.5×10^{10}
16	NN 05894 77246	Stream	0.9	0.15	1.143	13332	700	9.3×10^{10}
17	NN 05569 77177	Burn	2.6	0.28	1.149	72271	3100	2.2×10^{12}
18	NN 02261 78422	An t-Sùileag	17	0.98	0.895	1288284	900	1.2×10^{13}
19	NN 02380 78426	Ailt an Inbhir	2.2	0.3	3.135	178770	2200	3.9×10^{12}
20	NN 02679 78396	Stream	0.6	0.1	1.872	9704	2000	1.9×10^{11}
21	NN 02798 78390	Stream	0.7	0.32	1.202	23263	6200	1.4×10^{12}
22	NN 02995 78373	Stream	0.7	0.33	1.995	39817	4900	2.0×10^{12}
23	NN 03268 78353	Stream	0.6	0.08	1.752	7266	2300	1.7×10^{11}
24	NN 03387 78343	Stream	0.6	0.25	3.684	47745	1200	5.7×10^{11}
25	NN 03643 78352	Stream	2.45	0.25	1.206	63822	2500	1.6×10^{12}
26	NN 03852 78361	Stream	0.6	0.17	0.842	7420	6700	5.0×10^{11}
27	NN 03977 78365	Ailt na Croit Rainich	4.6	0.6	1.753	418027	700	2.9×10^{12}

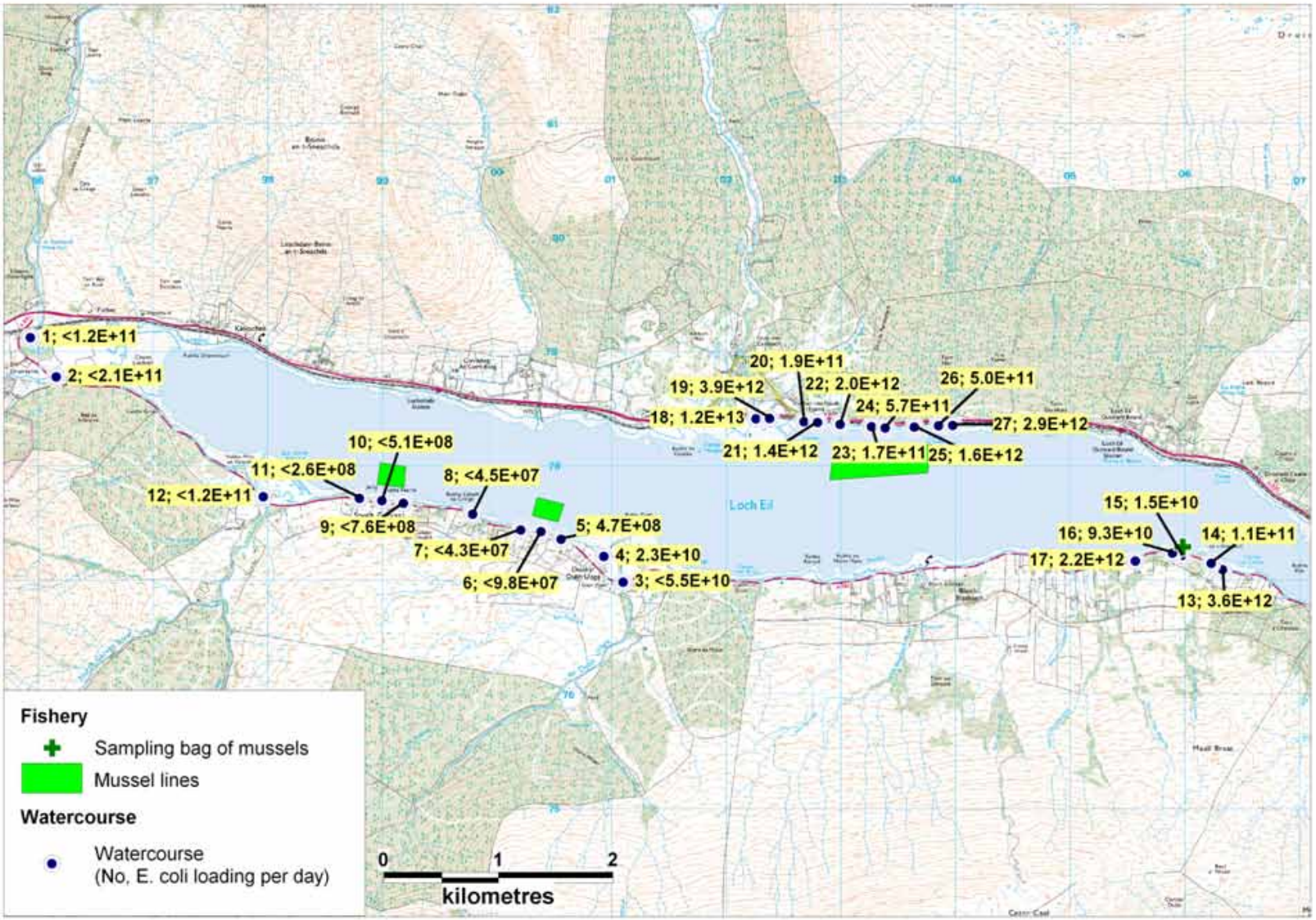


Figure 13.1 Map of river/stream loadings at Loch Eil

Where the bacterial loading is labelled on the map, the scientific notation is written in digital format, as this is the only format recognised by the mapping software. So, where normal scientific notation for 1000 is 1×10^3, in digital format it is written as 1E+3.

The watercourses identified as 1-12 in the table and map were sampled and measured on the 20/09/11 after only light rain, whereas those identified as 13-28 were sampled and measured on 21/09/11, after and during heavy rain. Visual comparison of those watercourses that had been passed on both days indicated that flows were markedly higher on the 21/09. All of the watercourses sampled on 21/09 showed *E. coli* concentrations of ≥700 *E. coli* cfu/100 ml whereas those sampled on 20/09 showed *E. coli* concentrations ≤300 *E. coli* cfu/100 ml, with the majority yielding results less than the limit of detection used for the samples. This difference applied irrespective of location around the loch. It is therefore not valid to directly compare the estimated loadings of samples taken over the two days. Under heavy rainfall conditions, the total loading determined in vicinity of Fassfern was greater than that in the vicinity of Rubha an-tSionnaich (i.e. the Loch Eil: Eil production area).

Most of the burns and streams recorded on the north were culverted under the road and railway although An t-Sùileag ran under a bridge. The smallest flows exited the sea wall via pipes.

There is significant freshwater input to the loch and this increases markedly following heavy rain. Loadings under rainfall conditions are high and pose a potential source of faecal contamination at all of the fisheries. Watercourses are located at several points in the vicinity of each fishery and therefore contamination may arise from several points on the shore side of each fishery following heavy rainfall. Information from one of the harvesters indicated that that the visible effects of significant freshwater input after heavy rain took about a week to clear during calm weather but only a couple of days during windy weather. In dry weather, some impact may arise from the main watercourses of Fionn Lighe, Dubh Lighe, Duisky River, Garvan River and An t-Sùileag. These would principally affect the fisheries at Garvan, Duisky and Fassfern.

14. Bathymetry and Hydrodynamics

The bathymetry of Loch Eil is shown in Figure 14.1. Loch Eil is approximately 12 km long from its head in the west to the outer part of the narrows at Corpach in the east. The width is fairly uniform, varying only between 0.9 and 1.2 km along much of the loch. The width at the narrows is 200 to 300 m. Although there are two sills, one at the eastern end of the narrows and the other in the vicinity of the Duisky mussel farm, Loch Eil will be presumed in this analysis to form one large basin (Edwards and Sharples, 1991). The maximum depth shown on the chart is 71 m: this occurs at the eastern end approximately 2 km west of the narrows. Depths at the Garvan and Duisky mussel farms vary between 5 and 30 m and at the Fassfern mussel farm between 12 and more than 50 m. Depths in the main channel at the narrows are less than 6 m. There is a drying area around much of the loch: this is most extensive at the head and near the mouths of the major watercourses.

14.1 Tidal Curve and Description

The two tidal curves shown in Figure 14.2 are for Corpach just outside the narrows that lie at the head of Loch Eil. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 BST on 19/09/11 and the second is for seven days beginning 00.00 BST on 26/09/11. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle, including the dates of the shoreline survey.

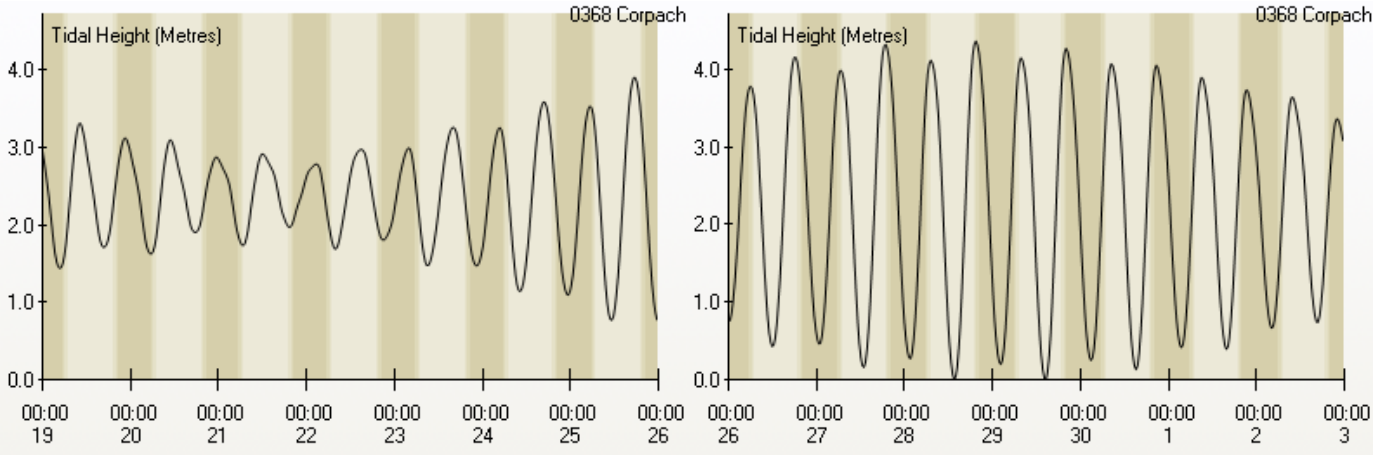


Figure 14.1 Tidal curves for Corpach

Following is the summary description for Corpach from TotalTide:

0368 Corpach is a Secondary Non-Harmonic port.
The tide type is Semi-Diurnal.

HAT	4.5 m
MHWS	4.0 m
MHWN	2.9 m
MSL	2.26 m
MLWN	1.6 m
MLWS	0.5 m
LAT	-0.2 m

Predicted heights are in metres above Chart Datum. The tidal range at spring tide is 3.5 m, and at neap tide 1.3 m, and so the area is mesotidal (moderate tidal range).

14.2 Currents

No tidal stream information was available for the vicinity of Loch Eil.

SEPA provided information on a current study undertaken at Garvan within Loch Eil. The location at which the current meter was deployed is shown in Figure 14.3: this lay at the northern edge of the present mussel lines at Garvan. The survey period was from 19/04/1999 to 19/05/1999.

Polar plots of the current directions and speeds, together with the wind direction and speeds over the same period, are shown in Figure 14.4. Median water depth at the current meter location during the survey was 33.4 m.

Tidal flows through The Narrows (also called Annat Narrows) is reported to be 5 knots (257.2 cm/s) at spring tides (Clyde Cruising Club, 2007). Tides within the loch are reported by the same source to run at 1-2 knots (51.4 - 102.8 cm/s), which concurs broadly with the speeds recorded during the current meter study. Contaminants originating to the east of The Narrows are likely to be carried westward into Loch Eil on the flood tide.

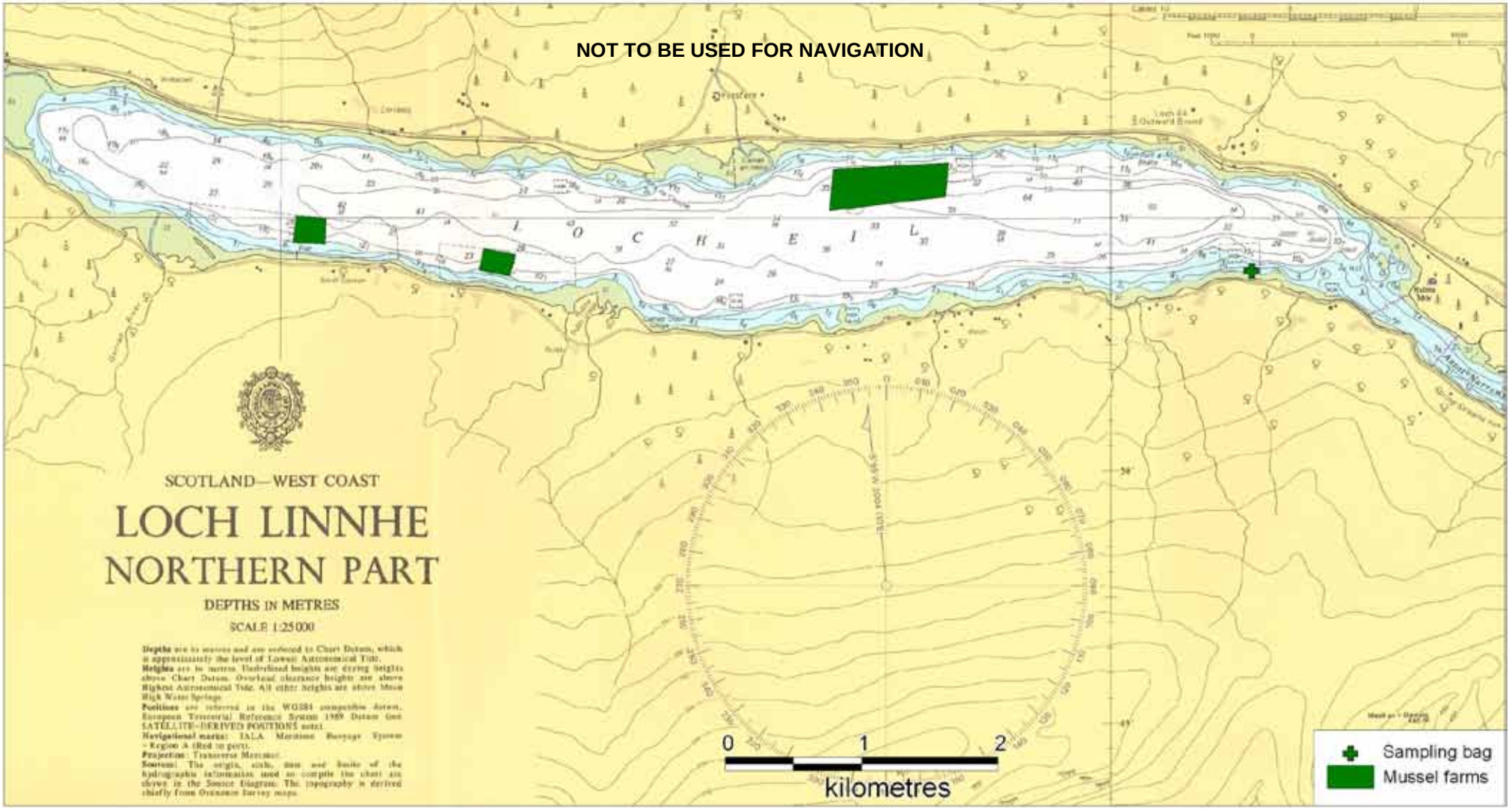


Figure 14.2 Bathymetry at Loch Eil

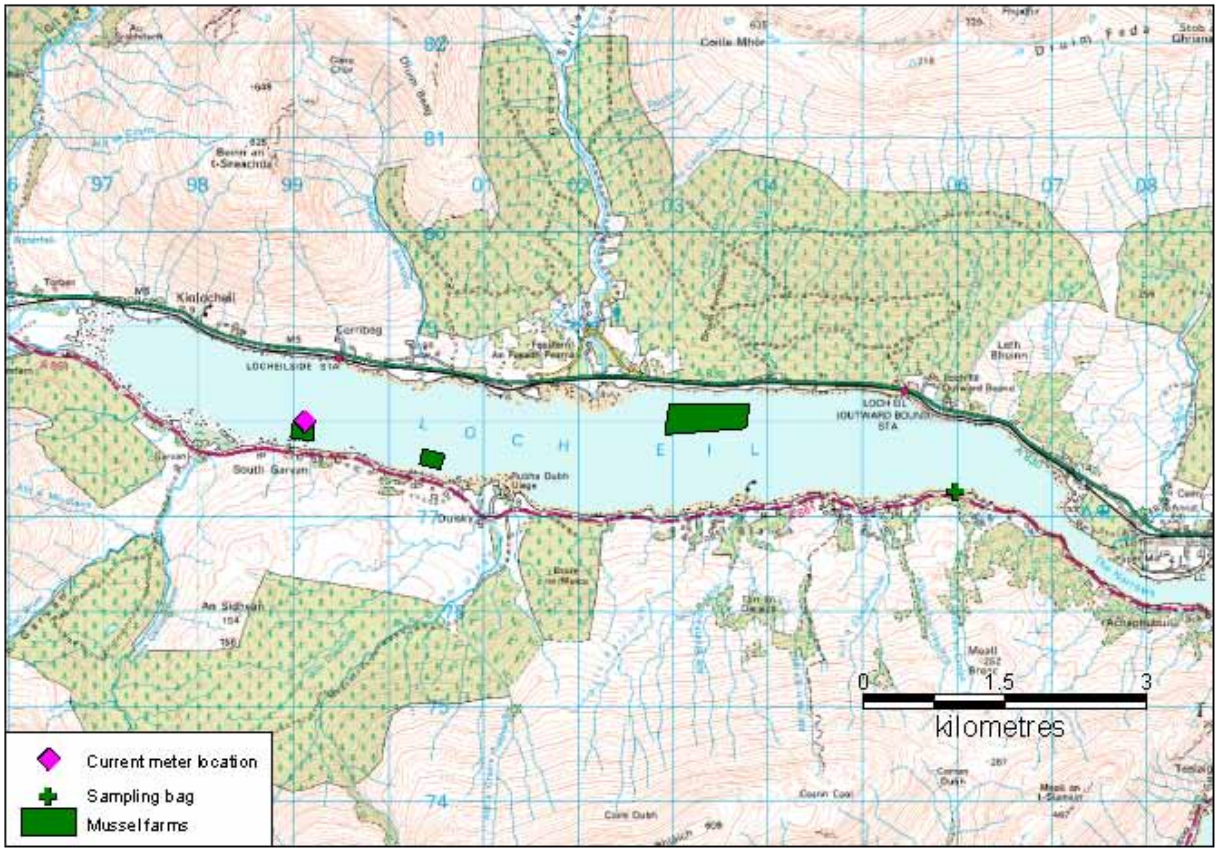


Figure 14.3 Current meter location at Garvan

The current plots all show blank areas at the centre. These represent periods when no measurable current was flowing. The effect was greatest at the near-bottom location. The pattern of currents varied markedly between the three depths. At the bottom, the flow was bidirectional, following the main axis of the loch. At mid-depth, the flow tended to be towards the head of the loch for much of the time and the direction of the strongest currents did not align exactly with the axis of the loch. Near the surface, the current direction was more variable, but generally tended towards the south and south-west. The effects seen at near-surface and mid-depth did not directly relate to the wind direction which tended to blow along the axis of the loch, with the predominating wind being towards the head. An additional plot of surface current speed and direction is given in Figure 14.5. This shows that the currents at the surface were similar to those near the bottom, although there was a smaller proportion of slack water at the surface. The predominant current direction at the surface did match the direction towards which the wind was blowing.

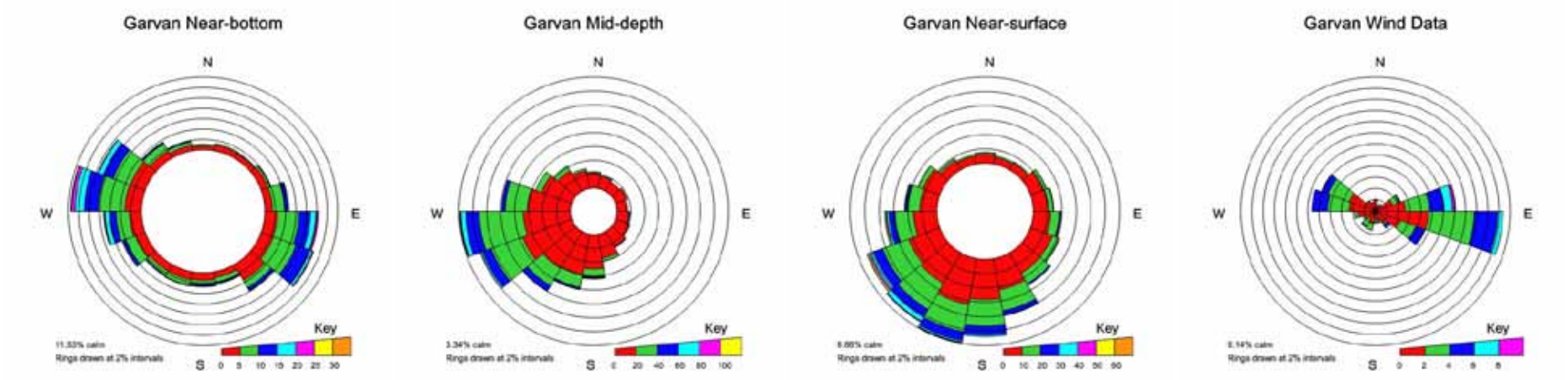


Figure 14.4 Current and wind plots for the Garvan current meter study

Currents measured in cm/s. Wind measured in m/s. As per convention, currents are plotted against the direction towards which they are travelling while winds are plotted against the direction from which they are travelling. The length of each segment in a plot relates to the proportion of observations lying in that direction. The speed relates to the colour key beneath each plot. The proportion that each colour takes up in an individual segment relates to the proportion of observations in that direction having speed in that range. Directions are in degrees magnetic.

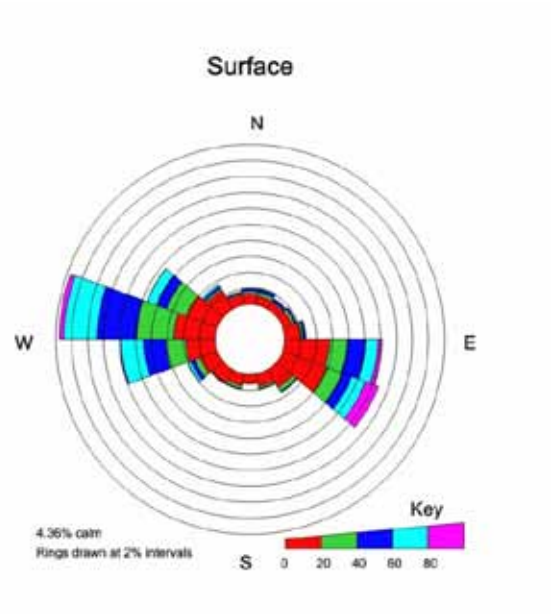


Figure 14.5 Surface currents at Garvan

Median and maximum current speeds at the various depths are shown in Table 14.1.

Table 14.1 Median and maximum current speeds at Garvan

Depth	Current speed (cm/s)	
	Median	Maximum
Surface	19	97
Near-surface	8	67
Mid-depth	13	105
Near-bottom	5	31

At a maximum current speed of 100 cm/s (1 m/s), contamination could be taken a distance of more than 14 km over a flood or ebb tide, ignoring the effects of dispersion or dilution. However, under average conditions, the transport distance would be in the region of 1 to 2 km. Current speeds at the narrows are markedly higher than within the loch and would enhance transport of contaminants from the east into Loch Eil, particularly on spring tides.

SEPA reported a very low residual current of 0.4 cm/s at the sea bed. They reported higher residual currents of 4.2 cm/s (at 195°) at near-surface and 7.5 cm/s (at 244°) at mid-depth.

14.3 Salinity profiles

Salinity profiles were taken at seven locations during the shoreline survey. These locations are shown in Figure 14.6 and the results are shown in Table 14.2.

Table 14.2 Salinity profiles at locations within Loch Eil

Number	Location	NGR	Depth	Salinity (ppt)	Temperature (°C)
1	Garvan – East	NM 9919 7781	Surface	19.8	12.4
			1 m	22.5	13.0
			3 m	24.2	13.1
			5 m	24.9	13.0
2	Garvan -West	NM 9898 7799	Surface	20.1	12.4
			1 m	22.0	12.9
			3 m	24.1	13.0
			5 m	24.8	13.0
3	Duisky -West	NN 0031 7759	Surface	21.1	12.9
			1 m	22.6	13.0
			3 m	24.3	13.0
			5 m	25.2	13.0
4	Duisky - East	NN 0053 7760	Surface	20.8	12.7
			1 m	22.9	13.0
			3 m	24.2	13.0
			5 m	25.0	13.0
5	Fassfern - West	NN 0293 7788	Surface	22.0	13.0
			1 m	23.0	13.2
			3 m	24.7	13.0
			5 m	25.3	13.0
6	Fassfern-East	NN 0379 7815	Surface	22.0	12.9
			1 m	23.2	13.0
			3 m	25.1	13.0
			5 m	26.0	13.0
7	Rubha ab t-Sionnaich	NN 0598 7730	Surface	21.7	13.2
			1 m	22.4	13.2
			3 m	24.6	13.1
			5 m	25.2	13.1

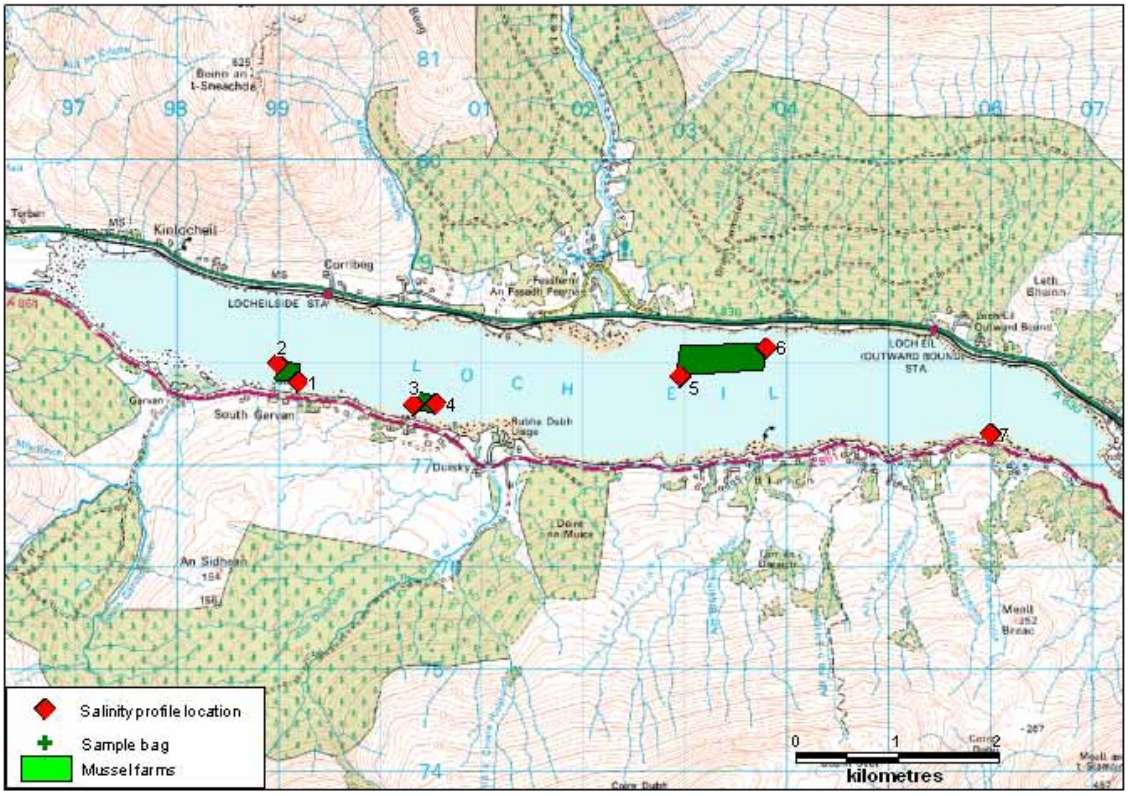


Figure 14.6 Salinity profile locations

The salinity reduction at the surface at each location was between 4.1 and 5.1 ppt compared with the value at 5 m. There was little difference in the values obtained at the different locations. It should be noted that during the shoreline survey Mr. Alan Byrne noted that the visible effects of significant freshwater input after heavy rain took about a week to clear during calm weather but only a couple of days during windy weather. There may therefore be more significant stratification during following heavy rainfall during periods of calm weather.

14.4 Conclusions

The body of Loch Eil is deep and, given that stratification is not marked, contamination will be subject to significant dilution within a short distance of the origin. The available information on currents within the loch indicates that these are generally low, and at the sea-bed and the surface flow along the main axis of the loch. Currents at depths in-between these do not necessarily follow that axis. The low current speeds mean that, in general, contamination will be taken relatively short distances from the source. Following heavy rainfall, contamination from run-off may be constrained to the upper layers. The length of persistence of a more contaminated upper layer will depend on the meteorological conditions.

Thus sources close to the mussel lines will be most significant in terms of potential sources of contamination. Available information indicates that, although currents will generally flow towards the head of the loch on the

incoming tide, and towards the mouth on the outgoing tide, the former will predominate at the depths of the mussel lines. This effect may vary with wind direction.

The Loch Eil: Eil production area is most likely to be affected by contamination arising from sources east of the loch and carried through the narrows. It is not clear whether the southern and northern shores would receive differing amounts of contamination via this pathway.

15. Shoreline Survey Overview

There are three production areas within Loch Eil: all are for mussels. At “Loch Eil”, there are two separate mussel longline farms, one at Garvan and one at Duisky. At “Loch Eil: Fassfern”, there is one mussel longline farm that consists of two distinct areas. At “Loch Eil: Eil”, there is no equipment on site and a line was maintained attached to a moored boat for the purposes of sampling.

Most of the properties on the northern shore are on mains sewerage but no Scottish Water assets were seen during the survey. Only one pipe was seen on the shoreline during the survey and this appeared to be redundant. It was assumed that the properties not on mains sewerage have septic tanks that discharge to soakaway. One pipe was seen at the shoreline and this appeared to be redundant. There are local concerns that sewage from caravans at Fassfern may enter a burn that enters the loch immediately to the east of the fishery. There is a large seasonal increase in population in the greater Fort William area, mainly in the summer months. Some of the accommodation is situated towards the mouth of the loch on the north side. Boating and shipping activity in the area is mainly located to the east of the narrows.

Much of the land immediately around the shores is deciduous woodland. Further up the slopes is coniferous forest and above this is rough grassland. There are several areas of shore grass/saltmarsh around the loch that is grazed by sheep. Sheep were seen in fields around the loch with the largest concentrations west of Fassfern. Small numbers of cattle were seen at locations on the southern side of the loch. Large numbers of gulls were seen in the vicinity of the Garvan and Duisky lines with the greatest concentration near Garvan: those lines are closest to a landfill site.

There was heavy rain during the second half of the survey and this affected both the number of small watercourses that were running and the size of the flows (as determined by observation rather than measurement). A large number of watercourses were sampled and measured during the survey. *E. coli* concentrations in those sampled before the heavy rain were all low while the *E. coli* concentrations in those sampled during and after the heavy rain were approximately 100-fold higher. The highest *E. coli* concentrations were seen in watercourses to the eastern end of the Fassfern lines.

Seawater samples were taken in the vicinity of the mussel lines and from the shore at several points. The highest results were seen in samples taken either side of the narrows on the incoming tide and in the vicinity of the Fassfern community sewage discharge. Salinity profiles taken near the mussel lines showed a markedly lower salinity towards the surface (approximately 5 ppt difference from bottom to top, varying with location).

Shellfish samples taken during the survey gave results that ranged from 310 to 2400 *E. coli* MPN/100 g with the higher results being seen in one of the samples fromeach of the production areas.

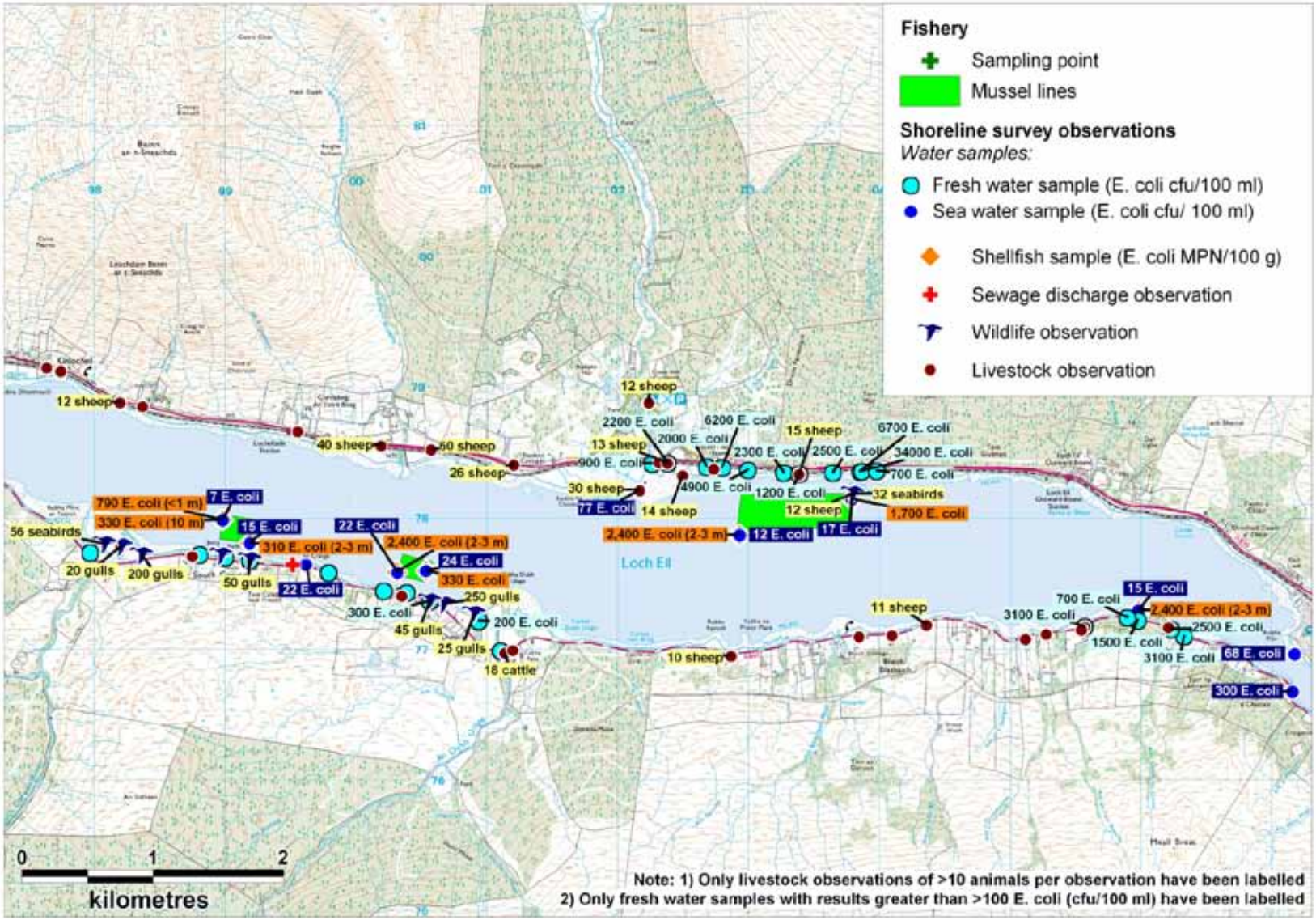


Figure 15.1 Summary of shoreline survey findings for Loch Eil

16. Overall Assessment

Human sewage impacts

One community septic tank at Fassfern discharges effluent to Loch Eil less than 1 km west of the Fassfern mussel farm, and is expected to affect water quality in the vicinity of the farm, particularly on the ebb tide. Most of the dwellings along the north shore of the loch either have private septic tanks discharging to soakaway or are connected to mains sewerage at Fassfern. The Outward Bound centre discharges to an adjacent watercourse, which in turn discharges to Loch Eil approximately 1km north of the sampling bag at Loch Eil: Eil and approximately 3 km east of the Fassfern mussel farm. Although the consent information received from SEPA suggests this is a very small discharge approximating a PE of 10, the centre accommodates up to 119 people overnight and therefore during busy periods is likely to discharge larger volumes of septic waste.

Two community sewage treatment plants discharge effluent to the upper reaches of Loch Linnhe, outside the entrance to Loch Eil. They have a combined population equivalent of over 25000. Treated effluent from these discharges would be expected to contribute an estimated maximum loading of up to 1.7×10^{13} faecal coliforms/day to the waters of upper Loch Linnhe, which could be expected to contribute to levels of faecal indicator bacteria in the eastern portion of Loch Eil, particularly at the Loch Eil: Eil production area.

Volumes of sewage discharged are likely to be significantly higher during summer, when the human population in the area is higher. Although no spill information was provided, spills from CSOs are likely to add significantly to bacterial loads in the loch. Operation of CSOs is driven by rainfall and/or snow melt runoff, and therefore will tend to operate more frequently when precipitation is typically higher. Analysis of rainfall data from the nearest Meteorological Office station identified higher rainfall, and higher peak rainfall, occurred from September to January for the period examined. Therefore it is likely that contamination levels in the eastern portion of Loch Eil will be higher during this period due to increased loadings contributed by sewage overlows.

The eastern end and northern shores of the loch are most likely to be impacted by human sewage, and in particular the Fassfern site which is located nearest a public sewage discharge. Any sites installed within the Loch Eil: Eil production area at the eastern end of the loch may be impacted by human sewage discharges at Corpach and Caol Spit to the east. There is likely to be seasonal variation in the input of human sewage to the loch, with greater volumes of sewage likely during the summer months when the tourist population is highest but a greater number of sewage overflows during autumn and winter, when rainfall is higher. However, no specific data was received on sewer overflows and therefore any seasonal variation in these cannot be properly assessed.

Agricultural impacts

The area around Loch Eil is used for extensive livestock production, primarily of cattle and sheep. Significant numbers of sheep were observed along the northern shore of the loch, to the north and west of the Fassfern site. Along the southern shore of the loch, cattle and sheep were observed near all the mussel farm sites, though in smaller numbers than observed along the northern shore. Livestock were observed to have access to watercourses and the shoreline, and droppings were observed on the shore along much of the loch. Therefore, livestock are likely to contribute significantly to faecal bacterial loads found at the fisheries. Although all sites are likely to be impacted to some extent from these sources, the impact is expected to be most acute at Fassfern, where a large number of sheep were observed.

Wildlife impacts

Wildlife are expected to contribute to background levels of faecal contamination throughout the loch, however in particular where streams enter the loch. Gulls were observed resting on the mussel floats and were a sufficient problem that a scarer had to be deployed on the mussel barge at Garvan. Direct deposition of guano to the mussel farm is likely to be highest near the barge and floats. The impact is likely to be highest at Garvan, with a smaller impact at Duisky. Any impact from nesting gulls east of the narrows is likely to be highest at the eastern side of the Loch Eil: Eil production area.

Seasonal variation

Historical monitoring results were found to vary significantly by season, with higher results in summer and autumn. Plots of results by month showed that for Loch Eil and Loch Eil: Fassfern production areas, there was a marked jump in results in July, which then decreased gradually toward December. At Loch Eil: Eil, the jump in results occurred in June. Results greater than 4600 *E. coli*/100 g were only seen from May to November. The analysis of variation with temperature showed that results at Loch Eil were not correlated with temperature, whereas there was statistically significant positive correlation between results and temperature at the other two production areas. If the seasonal variation was simply due to greater survival and/or uptake of *E. coli* then this correlation should have held for all three areas. Therefore, this suggests variation in source rather than bacterial survival is a more important driver of monitoring results.

Seasonal variation in human population and livestock population is likely to occur. The main tourist season in the Fort William area is from July to September, peaking in August. Numbers of sheep present are likely to be higher during summer and early autumn while lambs are present. Rainfall also varies by season, with much lower daily rainfall occurring from April to August and peak rainfall events≥40 mm/day occurring in all months except July.

A sharp increase was observed in monitoring results in June or July. This does not appear to correspond directly with rainfall, which tended to be lower at that time of year. However, it may be that the rainfall that does occur during drier periods has a greater likelihood of carrying higher levels of faecal

contamination to watercourses and the waters of the loch. No information was available on sewage overflows and so it is not clear whether there is a similar seasonal pattern to the frequency and/or duration of spills. Rainfall runoff is a prime pathway for transport of livestock faecal contamination to the loch. However at Loch Eil, there is also direct deposition to the shoreline and therefore the impact from livestock will not be so highly dependent on rainfall.

Rivers and streams

There is significant freshwater input to the loch and this increases markedly following heavy rainfall. Loadings under rainfall conditions are high and pose a potential source of faecal contamination at all of the fisheries. Watercourses are located at several points in the vicinity of each fishery and therefore contamination may arise from several points on the shore side of each fishery following heavy rainfall.

A significant correlation was found between *E. coli* result and rainfall in the previous 2 days for Loch Eil: Fassfern and Loch Eil: Eil but not for Loch Eil. A significant positive correlation was found between *E. coli* result and rainfall in the previous 7 days for Loch Eil but not for Loch Eil: Fassfern or Loch Eil: Eil. Where data was available, results greater than 46000 *E. coli*/100 g tended to occur after significant levels of rain (20 mm or more) in the 2 days prior to sampling. However, no significant correlation was found between the *E. coli* result and salinity for any of the production areas. Therefore, while the loch is significantly impacted by freshwater, the relationship between rainfall-related inputs and the *E. coli* results seen in the mussels is complex.

Wind-driven mixing is likely to be important in dilution of freshwater laden with faecal contaminants. In settled weather, contaminants may remain entrained in a layer of fresher water at the surface of the loch.

In dry weather, some impact may arise from the main watercourses of Fionn Lighe, Dubh Lighe, Duisky River, Garvan River and An t-Sùileag. These would principally affect the fisheries at Garvan, Duisky and Fassfern.

Movement of contaminants

Contamination will be subject to significant dilution within a short distance of the origin. Current speeds within the loch are generally low and flow along the main axis of the loch at the sea-bed and the surface. Currents at depths in-between these do not necessarily follow that axis. In general, contamination will be taken relatively short distances from the source. Following heavy rainfall, contamination from run-off may be constrained to the upper layers. The length of persistence of a more contaminated upper layer will depend on the meteorological conditions.

A weak but significant correlation was found at Loch Eil: Eil between *E. coli* results and the high/low tidal cycle: the highest results of 9200 *E. coli*/100 g were seen from just after high tide and during the first half of the ebb tide. This may reflect contamination that would have been swept over and past the site on the flood tide and was returning, together with any contamination arising west of the site, on the ebb tide.

At Loch Eil: Fassfern, the three highest results were seen on the flood tide which would imply a source to the east of the sampling locations.

Thus sources close to the mussel lines will be most significant in terms of potential sources of contamination. Available information indicates that, although currents will generally flow towards the head of the loch on the incoming tide, and towards the mouth on the outgoing tide, the former will predominate at the depths of the mussel lines. This effect may vary with wind direction, however it suggests that sources to the east of the mussel farms are more likely to impact on bacteriological quality of the mussels than those to the west. Significantly higher current speeds through the narrows is likely to carry contaminants arising to the east of the narrows westward into Loch Eil. These are most likely to impact on water quality particularly at the eastern end of the loch.

Temporal and geographical patterns of sampling results

No statistically significant difference was found between sampling results at the three production areas, although the geometric mean of sampling results was higher at Loch Eil: Fassfern and Loch Eil: Eil than at Loch Eil. The Loch Eil: Eil production area yielded a much higher proportion of samples greater than 4600 *E. coli* per 100g than did the other two production areas and is situated near the narrows at the mouth of the loch whereas the other two production areas are situated within the body of the loch.

Although the Loch Eil: Eil and Loch Eil: Fassfern production areas showed higher average levels of contamination than the Loch Eil production area, the difference was not found to be statistically significant.

There appeared to be a general increase in levels of *E. coli* in mussels over time for all three production areas, though this was most marked for Loch Eil: Eil prior to 2010 while the increase has been more steady at Loch Eil: Fassfern. At Loch Eil there appeared to be a sharp increase from 2011 onward. In general, this suggests an overall increase in bacterial contamination levels within the loch.

The time trend graphs showed that there appears to have been some increase in *E. coli* results over the period in all three production areas and all but one of the results greater than 4600 *E. coli*/ 100g occurred from July 2009 onward. Highest results were seen in summer and autumn and results greater than 4600 *E. coli*/100 g were only seen from May to November. A significant correlation was seen between *E. coli* results and water temperature at Loch Eil but not at the other two production areas.

Conclusions

The main sources of contamination to the loch are from diffuse contamination from livestock, and most likely from deer as well as septic discharges along the north shore and to the east at Corpach and Fort William. The main pathways for contamination are the large number of fresh watercourses discharging to the loch. These are likely to have significantly higher loadings

during rainfall. Given the variation in response, as seen in historical *E. coli* monitoring results, the areas should continue to be monitored separately. The highest risk from human faecal sources, and therefore human pathogenic viruses, is to the Fassfern and Loch Eil:Eil production areas. A stability assessment was carried out on all three areas, and the results did not support reduced monitoring frequency for any of the sites. Significant seasonal variation was seen in *E. coli* levels in mussels, with highest results in summer and autumn. Although no clear link was established between results and sources, an increase in human and livestock populations during this time is thought to be the most likely reason for the increase.

17. Recommendations

Assessment of the impact of sources combined with analysis of historical monitoring results against environmental factors suggests that the three areas are subject to different contaminating influences and therefore it is recommended that they continue to be monitored as separate production areas.

Although the site naming is clear, the naming of production areas is confusing and therefore it is suggested that the Loch Eil: Eil production area be renamed as Loch Eil: East to allow for clearer distinction from the Loch Eil production area.

All recommended boundaries and monitoring points are mapped for reference in Figure 17.1.

Loch Eil

Production area

No change is recommended to the production area boundaries.

RMP

It is recommended that the RMP be revised to NN 0052 7753. This lies on the southeast corner of the Duisky site, which is nearest significant watercourses with relatively high dry weather loadings.

Depth of sampling

Highest results during shoreline survey sampling were found to be at 2-3 metres depth, therefore it is recommended that monitoring samples be taken from this depth.

Tolerance

A standard tolerance of 40 metres is recommended to allow for some movement of the mussel lines.

Frequency

A stability assessment did not support reduced sampling and therefore it is recommended that monthly sampling be maintained.

Loch Eil: Fassfern

Production area

It is recommended that the production area boundary be curtailed on the western side to exclude the discharge from the Fassfern septic tank and along the south shore to exclude discharges from a private septic tank and land fill. Recommended boundaries are the described as the area bounded by lines drawn between NN 0260 7842 to NN 0275 7709 and NN 0275 7709 to NN 0444 7725 and NN 0444 7725 to NN 0440 7834 and extending to MHWS to the north.

RMP
It is recommended the RMP be revised to NN 0295 7815, which lies at the northwest corner of the Fassfern site and nearest to septic tank discharges along the northern shore.

Depth of sampling
Highest results during shoreline survey sampling were found to be at 2-3 metres depth, therefore it is recommended that monitoring samples be taken from this depth.

Tolerance
A standard tolerance of 40 metres is recommended to allow for some movement of the mussel lines.

Frequency
A stability assessment did not support reduced sampling and therefore it is recommended that monthly sampling be maintained.

Loch Eil: Eil (*Loch Eil East*)
Production area
It is recommended that the production area boundary be curtailed at the western edge to exclude the area around mouth of the watercourse to which the Outward Bound centre sewage discharges. The southern end of this boundary has also been amended to allow it to be clearly distinguishable by shoreline topography.

Recommended boundaries are the described as the area bounded by lines drawn between NN 0579 7806 to NN 0516 7715 and between NN 0700 7755 and NN 0700 7682 and extending to MHWS.

RMP
It is recommended the RMP be retained at the sampling bag currently situated along the southeastern shore of the Crown Estate lease area, at NN 0598 7730. It is recommended that the location be reevaluated when the mussel fishery has been put in place.

Depth of sampling
Highest results during shoreline survey sampling were found to be at 2-3 metres depth, therefore it is recommended that monitoring samples be taken from this depth.

Tolerance
A tolerance of 20 metres is recommended to allow for some movement of the sampling bag.

Frequency
A stability assessment did not support reduced sampling and therefore it is recommended that monthly sampling be maintained.

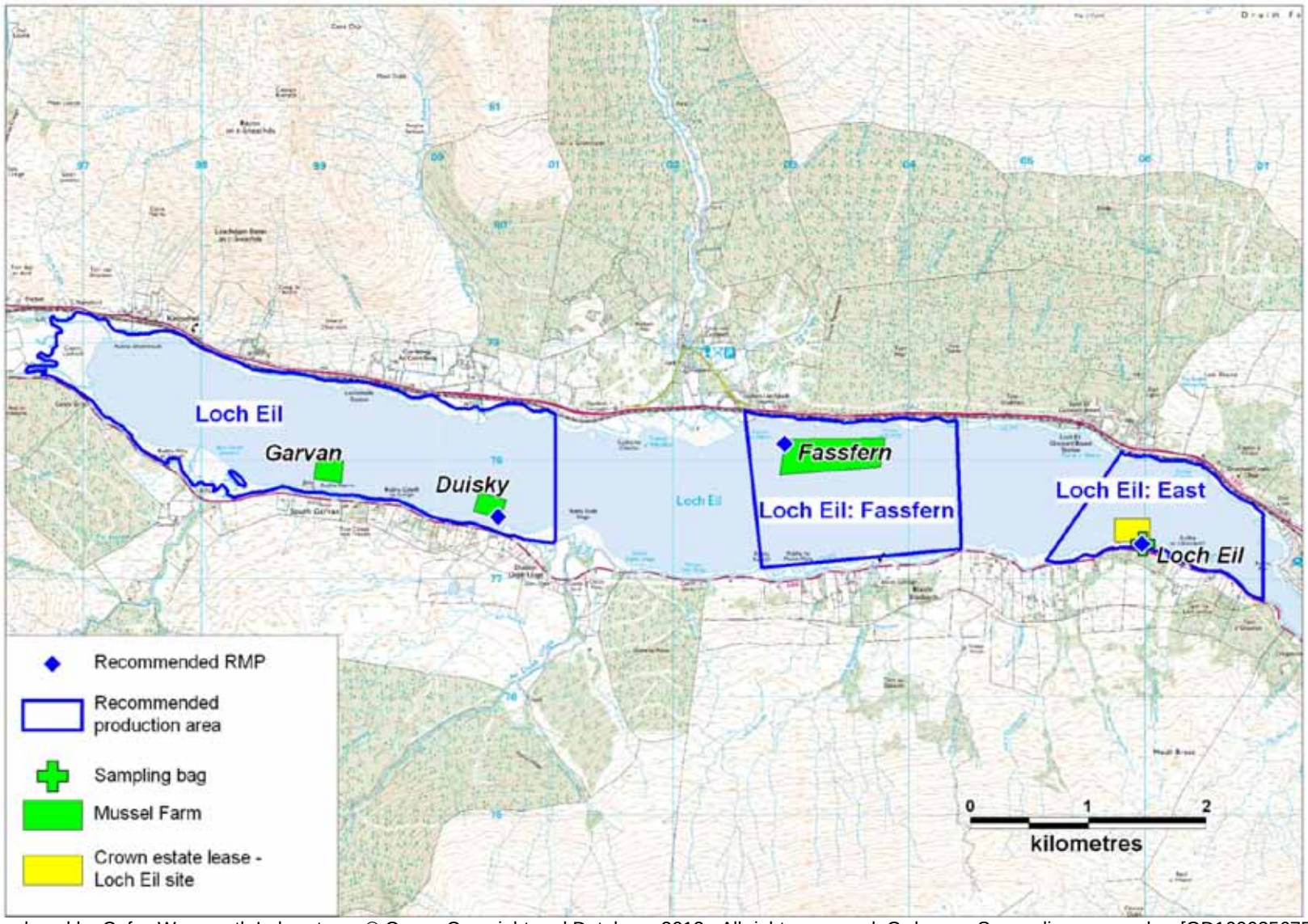


Figure 17.1 Map of recommendations at Loch Eil

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19. List of Figures and Tables

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Geology and Soils Assessment Method

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

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

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

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

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

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

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

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

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

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

Glossary of Soil Terminology

Calcareous: Containing free calcium carbonate.

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

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

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

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

General Information on Wildlife Impacts

Pinnipeds

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

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

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

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

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

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

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

Cetaceans

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

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

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

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

Birds

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

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

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

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

Deer

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

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

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

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

Other

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

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

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Tables of Typical Faecal Bacteria Concentrations

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

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

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

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

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

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

Statistical Data

Results for: Combined data

One-way ANOVA: LogEC versus Production_area

```
Source            DF      SS     MS     F      P
Production_area    2   1.227  0.614  1.04  0.357
Error            125  73.756  0.590
Total            127  74.983

S = 0.7681   R-Sq = 1.64%   R-Sq(adj) = 0.06%



Level                     N    Mean   StDev
134 (Loch Eil)           48  2.4377  0.7742
135 (Loch Eil: Eil)       33  2.6540  0.9101
136 (Loch Eil: Fassfern)  47  2.6283  0.6441

                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level                     ---------+---------+---------+---------+
134 (Loch Eil)            (----------*----------)
135 (Loch Eil: Eil)               (-------------*------------)
136 (Loch Eil: Fassfern)           (----------*-----------)
                          ---------+---------+---------+---------+
                                 2.40      2.60      2.80      3.00

Pooled StDev = 0.7681


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

Individual confidence level = 98.06%


Production_area = 134 (Loch Eil) subtracted from:

Production_area             Lower  Center   Upper
135 (Loch Eil: Eil)       -0.1952  0.2163  0.6277
136 (Loch Eil: Fassfern)  -0.1828  0.1906  0.5640

Production_area           -----+---------+---------+---------+----
135 (Loch Eil: Eil)              (-------------*-------------)
136 (Loch Eil: Fassfern)          (-----------*------------)
                          -----+---------+---------+---------+----
                            -0.30      0.00      0.30      0.60


Production_area = 135 (Loch Eil: Eil) subtracted from:

Production_area             Lower   Center   Upper
136 (Loch Eil: Fassfern)  -0.4389  -0.0257  0.3876

Production_area           -----+---------+---------+---------+----
136 (Loch Eil: Fassfern)  (-------------*-------------)
                          -----+---------+---------+---------+----
                            -0.30      0.00      0.30      0.60
```

General Linear Model: LogEC versus Season, Production_area

```
Factor           Type   Levels  Values
Season           fixed       4  1, 2, 3, 4
Production_area  fixed       3  134 (Loch Eil), 135 (Loch Eil: Eil), 136
(Loch
                                Eil: Fassfern)


Analysis of Variance for LogEC, using Adjusted SS for Tests

Source                   DF   Seq SS   Adj SS  Adj MS      F      P
Season                    3  14.6477  15.2064  5.0688  10.31  0.000
Production_area           2   0.8348   0.9019  0.4509   0.92  0.402
Season*Production_area    6   2.4785   2.4785  0.4131   0.84  0.541
Error                   116  57.0216  57.0216  0.4916
Total                   127  74.9827


S = 0.701118   R-Sq = 23.95%   R-Sq(adj) = 16.74%


Unusual Observations for LogEC

Obs    LogEC      Fit   SE Fit  Residual  St Resid
  9  1.60206  3.06287  0.22171  -1.46081     -2.20 R
 13  1.00000  2.60833  0.18738  -1.60833     -2.38 R
 72  3.54407  2.32306  0.35056   1.22100      2.01 R
 75  3.96379  1.79722  0.28623   2.16657      3.39 R
 93  1.30103  2.67801  0.18738  -1.37698     -2.04 R
 94  1.30103  2.67801  0.18738  -1.37698     -2.04 R

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

General Linear Model: LogEC versus Season

```
Factor  Type   Levels  Values
Season  fixed       4  1, 2, 3, 4


Analysis of Variance for LogEC, using Adjusted SS for Tests

Source   DF   Seq SS   Adj SS  Adj MS      F      P
Season    3  14.6477  14.6477  4.8826  10.03  0.000
Error   124  60.3350  60.3350  0.4866
Total   127  74.9827


S = 0.697547   R-Sq = 19.53%   R-Sq(adj) = 17.59%


Unusual Observations for LogEC

Obs    LogEC      Fit   SE Fit  Residual  St Resid
  9  1.60206  3.00275  0.12528  -1.40069     -2.04 R
 13  1.00000  2.71048  0.11029  -1.71048     -2.48 R
 19  1.00000  2.38080  0.13951  -1.38080     -2.02 R
 75  3.96379  2.09687  0.12331   1.86692      2.72 R
 93  1.30103  2.71048  0.11029  -1.40945     -2.05 R
 94  1.30103  2.71048  0.11029  -1.40945     -2.05 R

R denotes an observation with a large standardized residual.


Tukey 95.0% Simultaneous Confidence Intervals
Response Variable LogEC
All Pairwise Comparisons among Levels of Season
Season = 1  subtracted from:

Season    Lower  Center   Upper  ------+---------+---------+---------+
```

```
2        0.1831  0.6136  1.0441                    (-----*-----)
3        0.4485  0.9059  1.3633                       (------*-----)
4       -0.2006  0.2839  0.7684                 (------*------)
                                  ------+---------+---------+---------+
                                     -0.70      0.00      0.70      1.40


Season = 2  subtracted from:

Season    Lower   Center   Upper  ------+---------+---------+---------+
3       -0.1421   0.2923  0.7266                (-----*-----)
4       -0.7924  -0.3297  0.1331       (-----*------)
                                  ------+---------+---------+---------+
                                     -0.70      0.00      0.70      1.40


Season = 3  subtracted from:

Season   Lower   Center    Upper  ------+---------+---------+---------+
4       -1.110  -0.6220  -0.1340  (------*------)
                                  ------+---------+---------+---------+
                                     -0.70      0.00      0.70      1.40


Tukey Simultaneous Tests
Response Variable LogEC
All Pairwise Comparisons among Levels of Season
Season = 1  subtracted from:

        Difference       SE of           Adjusted
Season    of Means  Difference  T-Value   P-Value
2           0.6136      0.1654    3.709    0.0018
3           0.9059      0.1758    5.153    0.0000
4           0.2839      0.1862    1.525    0.4258


Season = 2  subtracted from:

        Difference       SE of           Adjusted
Season    of Means  Difference  T-Value   P-Value
3           0.2923      0.1669    1.751    0.3021
4          -0.3297      0.1778   -1.854    0.2535


Season = 3  subtracted from:

        Difference       SE of           Adjusted
Season    of Means  Difference  T-Value   P-Value
4          -0.6220      0.1875   -3.317    0.0065
```

Hydrographic Methods

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

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

Background processes

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

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

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

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

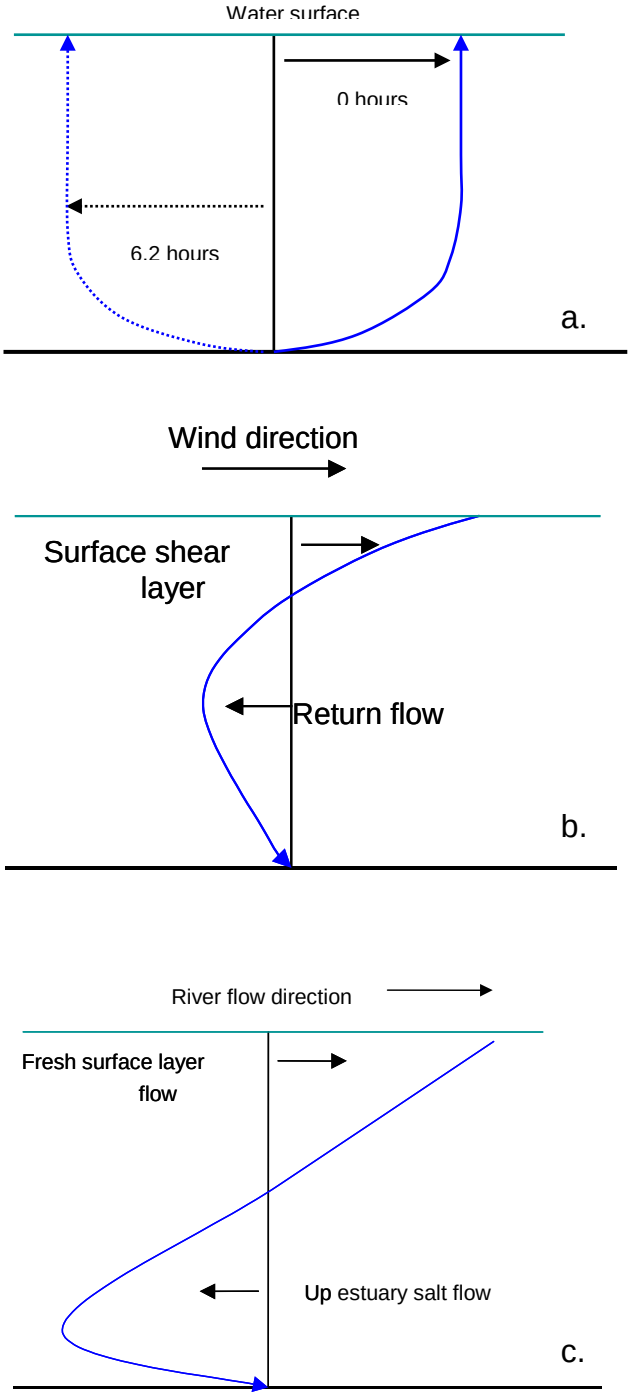

Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

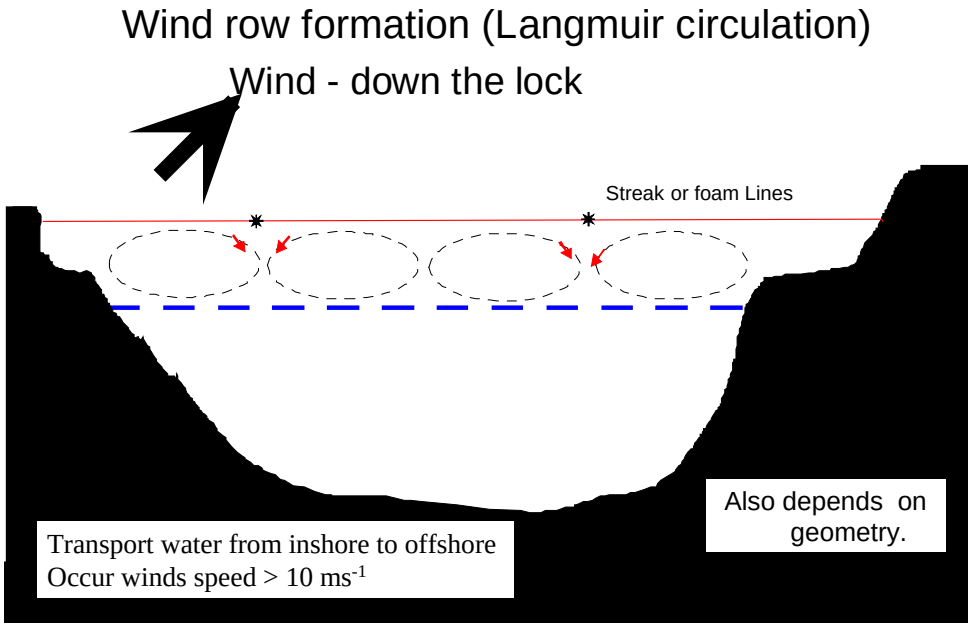

Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Non-modelling Assessment

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

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

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

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

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

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

References

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

Glossary

The following technical terms may appear in the hydrographic assessment.

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

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

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

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

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

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

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

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

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

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

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

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

Shoreline Survey Report

Prod. area:	}See Table 1.
Site name:	}
Species:	Common mussels
Harvester:	Loch Eil and Loch Eil: Fassfern – Alan & Lawrie Byrne, Fassfern Mussels Loch Eil: Eil – James MacLean, Silversea Mussels
Local Authority:	The Highland Council - Lochaber
Status:	Existing
Date Surveyed:	19-22/09/11
Surveyed by:	Ron Lee and Steve Lewis
Existing RMP:	
Area Surveyed:	Head of loch and shores adjacent to the mussel sites at Garvan, Duisky, Fassfern & near Rubha ab t-Sionnaich. Animal number observations undertaken round whole loch.

Table 1. Production areas and sites

Production area	Site	SIN
Loch Eil	Duisky	HL-134-216-08
	Garvan	HL-134-217-08
Loch Eil: Eil	Loch Eil	HL-135-218-08
Loch Eil: Fassfern	Fassfern	HL-136-219-08

Weather observations

19/09/11: Dry overnight. Intermittent light showers. Very light breeze.
20/09/11: Some rain overnight. Intermittent showers. Wind F2/3.
21/09/11: Rain overnight. Heavy rain interspersed with showers. Wind F3/4 gusting F5/6 or stronger.
22/09/11: Rain overnight. Intermittent showers. Wind 3/4 gusting to F5.

Acknowledgement

We are grateful to Mr Alan Byrne for providing a boat and his time to enable the surveying and sampling of the mussel lines.

Site Observations

Observations are listed in Table 2 and the locations shown in the maps in Figures 1 (West) and 2 (East).

Fishery

Loch Eil

Garvan Six double-headed lines with 7 to 10 m droppers. Will be changing to all 6 m droppers.

Duisky Five double-headed lines with 7 to 10 m droppers. Will be changing to all 6 m droppers.

Loch Eil: Fassfern Two separate (west and east) areas each containing 6 double headed continuous lines. The outer line in each area has drifted and will be moved inside of the second line in the near future, as well as approximately about 80 m to the east.

Loch Eil: Eil No rafts or long lines were in the water at the previous mussel farm site. The rafts that had been there had been removed. Some of the equipment was on the shore. A single dropper line was kept attached to a moored boat for the purposes of sampling. The sampling officer stated that the harvester had identified the intention to replace the rafts with lines.

Sewage/Faecal Sources

No Scottish Water equipment was seen during the survey although a large proportion of properties on the northern shore are on mains sewerage. Other properties on the north side, and those on the south side, will have private septic tanks. Most of these will go to soakaway or to water courses as only one pipe was seen at the shoreline and this appeared to be redundant. A seawater sample was taken in the vicinity of the community discharge at Fassfern. There are local concerns that sewage from caravans at Fassfern may enter a burn that enters the loch immediately to the east of the fishery.

The greater Fort William area is the largest potential source of sewage at the eastern end of the loch – seawater samples were taken on the incoming tide at both sides of the narrows in order to try to determine the potential impact of this.

Seasonal Population

There is a large tourist influx to the Fort William area where there are a large number of hotels, guest houses and other forms of tourist accommodation. Specific information was obtained from the visitor centre for use in the population section of the full report. Around the shores of Loch Eil the main tourist centre is the Linnhe holiday park at the western end of the narrows on the northern side of the loch . There is also an Outward Bound centre, a small number of other activity centres and some guesthouses/B&Bs.

Despite Fort William and the surrounding area being known for its outdoor activities, the main season for visitors is from July to September with a marked peak in August.

Boats/Shipping

The Caledonian Canal starts at Corpach and is very popular with leisure boats and canoeists. An appraisal has been undertaken towards a marina at the lower end of the canal but this has not yet even reached the detailed planning stage. Corpach Harbour is a small industrial port. There are some yacht moorings at the top of Loch Linnhe but few moorings within Loch Eil itself.

Land Use

Around much of the loch, there is deciduous woodland with fern undergrowth near the shore, coniferous forests on the lower hill slopes and rough grassland and heather above. There are several areas of shore grass/saltmarsh around the loch and this is grazed by sheep. Some sheep droppings were seen on the southern shoreline while moderate amounts were seen along the northern shoreline in the vicinity of the Fassfern fishery. Sheep were also seen in fields around the loch: the largest concentrations were on the northern side of the loch west of Fassfern. Small numbers of cattle were seen at locations on the southern side of the loch. Some of these were said to graze the grass at the head of the loch.

There is an industrial area around Corpach harbour with a large sawmill facility and other shipping storage. There is a small industrial estate located near the harbour.

Wildlife/Birds

Large numbers of gulls were seen in the vicinity of the Garvan and Duisky lines with the greatest concentration on the shore and seawater near the former. Gulls and some cormorants were sitting on the mussel floats. A bird scarer is used to try to keep gulls off the work raft at the Garvan site.

Other

Alan Byrne noted that the visible effects of significant freshwater input after heavy rain took about a week to clear during calm weather but only a couple of days during windy weather. He also noted that there had been local concerns about possible sewage pollution of a burn located at the eastern end of the Fassfern site. He also identified the intention to add toilet facilities to the work barge based in the loch, though a decision had not yet been made as to whether a chemical toilet or holding tank would be employed for handling waste.

Recorded observations apply to the date of survey only. Animal numbers were recorded on the day from the observer's point of view. This does not necessarily equate to total numbers present as natural features may obscure individuals and small groups of animals from view.

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

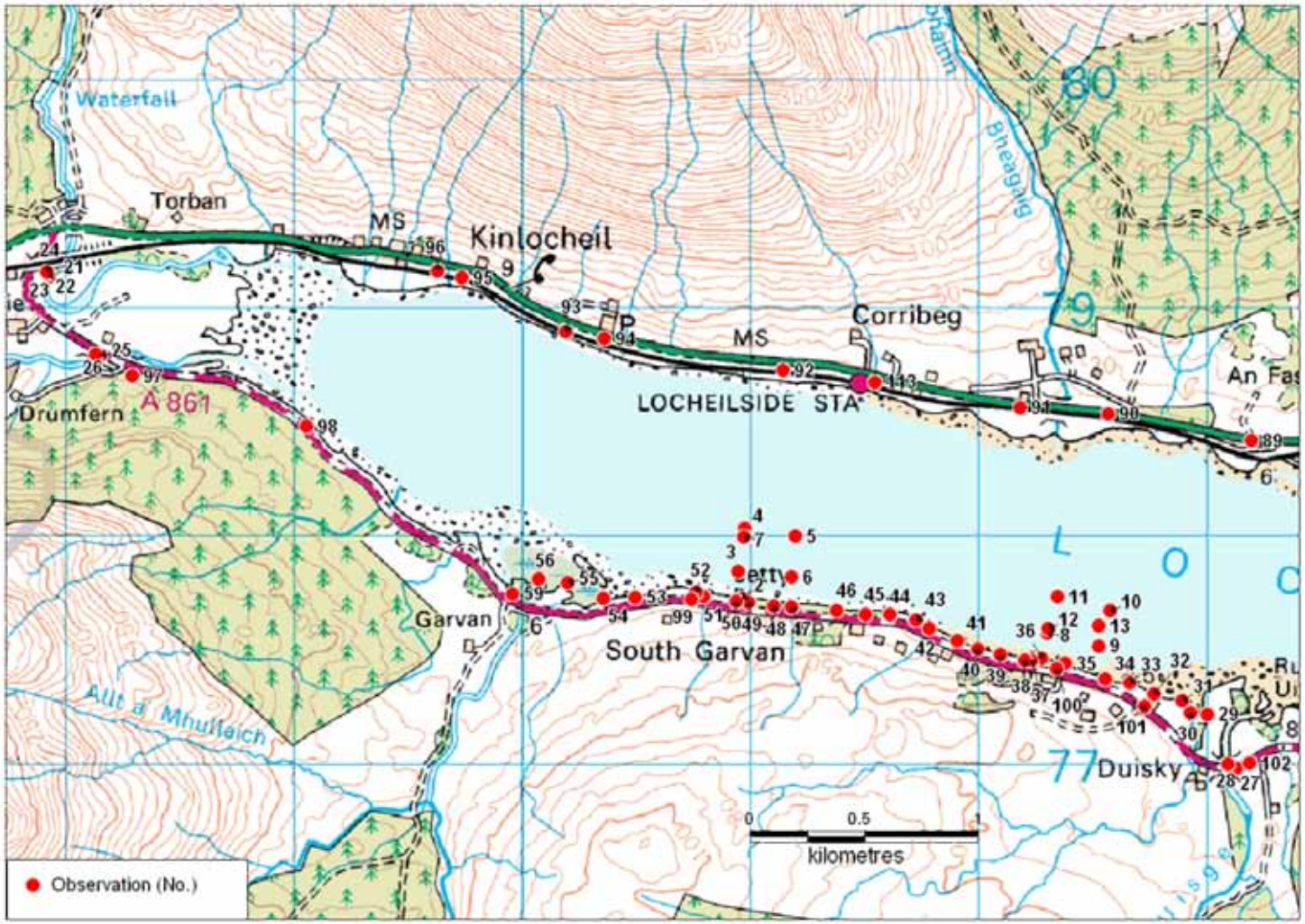

Figure 1. Map of Shoreline Observations: West

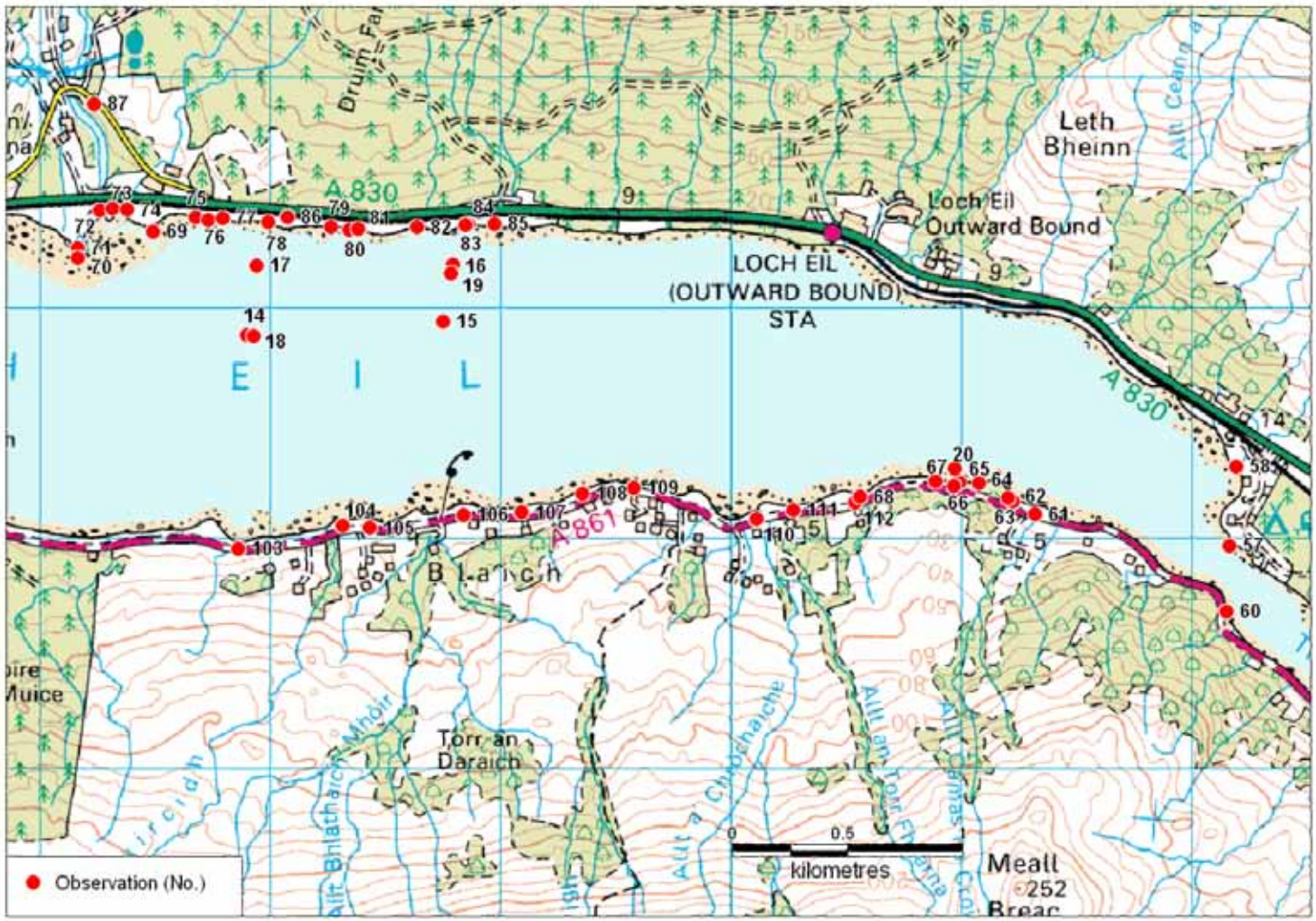

Figure 2. Map of Shoreline Observations: East

Table 2. Shoreline Observations

No.	Date	Time	NGR	Easting	Northing	Associated photograph	Sample	Description
1	19/09/11	09:32	NN 09157 58606	209157	758606			Mussel Farm base
2	19/09/11	09:53	NM 98969 77720	198969	777720			Slipway. for mussel base. Swan nearby
3	19/09/11	09:57	NM 98953 77840	198953	777840			Garvan lines corner
4	19/09/11	10:01	NM 98981 78030	198981	778030			Garvan lines corner
5	19/09/11	10:02	NM 99202 77995	199202	777995			Garvan lines corner
6	19/09/11	10:04	NM 99187 77814	199187	777814		LEM1; LEW01	Garvan lines corner; salinity profile: 5m 24.9 ppt 13.0°C; 3 m 24.2 ppt 13.1°C; 1 m 22.5 ppt 13.0°C; surf 19.8 ppt 12.4°C; seawater and mussel samples
7	19/09/11	10:26	NM 98978 77992	198978	777992		LEM2 top; LEM3 10 m; LEW02	Seawater and mussel samples; salinity profile: 5 m 24.8 ppt 13.0°C; 3 m 24.1 ppt 13.0°C; 1 m 22.0 ppt 12.9°C; surf 20.1 ppt 12.4°C
8	19/09/11	10:49	NN 00308 77567	200308	777567			Duisky lines corner
9	19/09/11	10:51	NN 00532 77511	200532	777511	Figure 6		Duisky lines corner
10	19/09/11	10:54	NN 00583 77666	200583	777666			Duisky lines corner
11	19/09/11	10:56	NN 00351 77727	200351	777727			Duisky lines corner
12	19/09/11	10:57	NN 00313 77590	200313	777590		LEW03	Classification sample location (2-3 m); seawater sample; salinity profile: 5 m 25.2 ppt 13.0°C; 3 m 24.3 ppt 13.0°C; 1 m 22.6 ppt 13.0°C; surf 21.1 ppt 12.9°C

No.	Date	Time	NGR	Easting	Northing	Associated photograph	Sample	Description
13	19/09/11	11:09	NN 00533 77601	200533	777601		LEM4; LEW04	Seawater and mussel samples; salinity profile: 5 m 25.0 ppt 13.0°C; 3 m 24.2 ppt 13.0°C; 1 m 22.9 ppt 13.0°C; surf 20.8 ppt 12.7°C
14	19/09/11	11:23	NN 02903 77880	202903	777880			Fassfern lines corner
15	19/09/11	11:26	NN 03755 77942	203755	777942			Fassfern lines corner
16	19/09/11	11:28	NN 03796 78190	203796	778190			Fassfern lines corner; 2 cormorants and 30 gulls on floats; 12 sheep on shore to east
17	19/09/11	11:30	NN 02943 78184	202943	778184			Fassfern lines corner
18	19/09/11	11:33	NN 02930 77875	202930	777875		LEM5 (2-3 m); LEW05	Seawater and mussel samples; salinity profile: 5 m 25.3 ppt 13.0°C; 3 m 24.7 ppt 13.0°C; 1 m 23.0 ppt 13.2°C; surf 22.0 ppt 13.0°C
19	19/09/11	11:49	NN 03789 78151	203789	778151		LEW06	Classification sample location (2-3 m); seawater sample; salinity profile: 5 m 26.0 ppt 13.0°C; 3 m 25.1 ppt 13.0°C; 1 m 23.2 ppt 13.0°C; surf 22.0 ppt 12.9°C
20	19/09/11	12:15	NN 05980 77301	205980	777301		LEW07	Loch Eil: Eil site; no mussel farm equipment on site; line for sampling attached to open boat; classification sample location (2-3 m); salinity profile: 5 m 25.2 ppt 13.1°C; 3 m 24.6 ppt 13.1°C; 1 m 22.4 ppt 13.2°C; surf 21.7 ppt 13.2°C
21	20/09/11	09:15	NM 95927 79133	195927	779133			One side of river; cattle tracks along side of river and loch but no cattle seen
22	20/09/11	09:17	NM 95930 79133	195930	779133	Figure 7	LEW08	Same side of river; Approx 4 m out: depth 50 cm, flow 0.221 m/s; freshwater sample
23	20/09/11	09:28	NM 95921 79147	195921	779147			Second side of river
24	20/09/11	09:30	NM 95920 79153	195920	779153			Same side of river; about 4 m out: depth 45 cm, flow 0.081 m/s

No.	Date	Time	NGR	Easting	Northing	Associated photograph	Sample	Description
25	20/09/11	09:48	NM 96156 78789	196156	778789	Figure 8	LEW09	River width 10.30 m; 1/3 way out: depth 27 cm, flow 0.405 m/s; 1/3 way from other side: 48 cm, flow 0.772 m/s; freshwater sample
26	20/09/11	09:53	NM 96136 78794	196136	778794			Land drain, not flowing
27	20/09/11	10:10	NN 01136 76978	201136	776978			10 highland cattle in field; mixed deciduous and coniferous woodland with coniferous forest above. Field on other side.
28	20/09/11	10:13	NN 01102 76993	201102	776993		LEW10	Duisky River. Width 3.70 m, depth 50 cm, flow 0.342 m/s. Freshwater sample.
29	20/09/11	10:24	NN 01009 77213	201009	777213			Touring caravan permanently parked. Grass around.
30	20/09/11	10:30	NN 00935 77219	200935	777219		LEW11	Burn. Width 4.20 m, depth 18 cm, flow 0.176 m/s. Freshwater sample
31	20/09/11	10:39	NN 00898 77273	200898	777273	Figure 9		25 gulls offshore. Photograph towards Duisky lines.
32	20/09/11	10:42	NN 00776 77303	200776	777303			Land run-off
33	20/09/11	10:46	NN 00668 77349	200668	777349			Approx 150 gulls on shore and approx 100 offshore. Near to landfill site.
34	20/09/11	10:49	NN 00562 77368	200562	777368		LEW12	Small stream from pipe. Width 50 cm, depth 9 cm, flow 0.040 m/s. Freshwater sample. Approx 45 black-backed gulls standing on near-shore mussel floats.
35	20/09/11	10:59	NN 00384 77435	200384	777435		LEW13	Very small stream. Width 19 cm, depth 2 cm, flow 0.299 m/s. Freshwater sample.
36	20/09/11	11:07	NN 00284 77457	200284	777457			Yacht stored above shore
37	20/09/11	11:08	NN 00239 77448	200239	777448			Makeshift slip. Mussel farm gear and two fishing boats stored above shore.

No.	Date	Time	NGR	Easting	Northing	Associated photograph	Sample	Description
38	20/09/11	11:11	NN 00209 77448	200209	777448		LEW14	Very small stream. Width 25 cm, depth 9 cm, flow 0.022 m/s. Freshwater sample.
39	20/09/11	11:18	NN 00101 77475	200101	777475			Very small stream: not sampled or measured.
40	20/09/11	11:22	NN 00002 77500	200002	777500			Very small stream: not sampled or measured.
41	20/09/11	11:25	NM 99913 77536	199913	777536			Land run-off. Long-dead sheep nearby.
42	20/09/11	11:29	NM 99789 77589	199789	777589		LEW15	Stream. Width 43 cm, depth 8 cm, flow 0.015 m/s. Freshwater sample.
43	20/09/11	11:34	NM 99731 77626	199731	777626			4 sea kayakers.
44	20/09/11	11:43	NM 99616 77651	199616	777651		LEW16	Seawater sample. Deciduous woodland with fern undergrowth down to shore.
45	20/09/11	11:47	NM 99511 77652	199511	777652			Land run-off. Nearby rusty outfall pipe – no flow or evidence of recent use.
46	20/09/11	11:52	NM 99382 77669	199382	777669			Land run-off.
47	20/09/11	11:56	NM 99186 77684	199186	777684		LEW17	Stream. Width 90 cm, depth 7 cm, flow 0.140 m/s. Freshwater sample. Approx 50 gulls on mussel floats.
48	20/09/11	12:03	NM 99107 77686	199107	777686			Land run-off
49	20/09/11	12:06	NM 98998 77705	198998	777705		LEW18	Small stream. Width 65 cm, depth 9 cm, flow 0.100 m/s. Freshwater sample.
50	20/09/11	12:11	NM 98942 77710	198942	777710			Mussel farm gear on shore. Plus pontoons. Green algae on shore.
51	20/09/11	12:15	NM 98802 77727	198802	777727		LEW19	Stream. Width 95 cm, depth 8 cm, flow 0.039 m/s. Freshwater sample.

No.	Date	Time	NGR	Easting	Northing	Associated photograph	Sample	Description
52	20/09/11	12:20	NM 98768 77749	198768	777749			Land run-off.
53	20/09/11	12:26	NM 98502 77725	198502	777725			Very small stream. Not measured or sampled.
54	20/09/11	12:29	NM 98360 77722	198360	777722			Small stream. Not measured or sampled. Approx. 200 gulls on nearby promontory.
55	20/09/11	12:32	NM 98203 77790	198203	777790			Grassy foreshore with approx 20 gulls. Very small stream nearby. Sheep droppings.
56	20/09/11	12:36	NM 98076 77806	198076	777806			Approx 50 gulls, 1 swan and 6 oystercatchers at edge of shore.
57	21/09/11	07:45	NN 07174 76966	207174	776966		LEW21	Seawater sample below Linnhe Holiday Park (large number of mobile homes and some chalets)
58	21/09/11	07:51	NN 07203 77310	207203	777310			Large culverted burn – not measured or sampled
59	21/09/11	08:07	NM 97964 77742	197964	777742	Figure 10	LEW20	Garvan River. Width 11.80 m, 1/3 across: depth 37 cm, flow 0.371 m/s.2/3 across: depth 29 cm, flow 0.337 m/s. Freshwater sample. Recheck of location: actually sampled and measured on 20/09/11 at 10:00.
60	21/09/11	08:25	NN 07160 76679	207160	776679		LEW22	Seawater sample
61	21/09/11	08:50	NN 06329 77103	206329	777103	Figure 11	LEW23	Culverted burn. Width 1.85 m, depth 35 cm, flow 2.087 m/s. Freshwater sample.
62	21/09/11	08:58	NN 06230 77156	206230	777156		LEW24	Small stream. Width 42 cm, depth 13 cm, flow 0.903 m/s. Freshwater sample. Fields and deciduous woodland above shore.
63	21/09/11	09:03	NN 06211 77173	206211	777173			Land run-off. Some sheep droppings on foreshore.
64	21/09/11	09:07	NN 06083 77237	206083	777237			Some disused mussel farm equipment on shore.

No.	Date	Time	NGR	Easting	Northing	Associated photograph	Sample	Description
65	21/09/11	09:11	NN 06002 77241	206002	777241			Small boat with sampling line offshore. Small boat and some mussel farm equipment onshore. Deciduous woodland.
66	21/09/11	09:14	NN 05975 77225	205975	777225		LEW25	Small stream through pipe. Width 30 cm, depth 4 cm, flow 0.985 m/s. Freshwater sample.
67	21/09/11	09:19	NN 05894 77246	205894	777246		LEW26	Stream. Width 90 cm, depth 15 cm, flow 1.143 m/s. Freshwater sample.
68	21/09/11	09:29	NN 05569 77177	205569	777177		LEW27	5 sheep on shore. Burn: width 2.6 m, depth 28 cm, flow 1.149 m/s. Freshwater sample.
69	21/09/11	10:20	NN 02496 78333	202496	778333			14 sheep and moderate amount of sheep droppings on foreshore. Grass.
70	21/09/11	10:32	NN 02168 78218	202168	778218		LEW28	Approx 30 sheep and moderate amount of droppings on foreshore. Seawater sample.
71	21/09/11	10:34	NN 02167 78261	202167	778261			Trig. point
72	21/09/11	10:39	NN 02261 78422	202261	778422	Figure 12	LEW29	River by rail bridge. Width 17 m, depth 98 cm, flow 0.895 m/s. Freshwater sample.
73	21/09/11	10:49	NN 02317 78432	202317	778432			4 sheep
74	21/09/11	10:50	NN 02380 78426	202380	778426		LEW30	Burn. Width 2.2 m, depth 30 cm, flow 3.135 m/s. Freshwater sample. 13 sheep.
75	21/09/11	11:03	NN 02679 78396	202679	778396		LEW31	Stream through sea wall. Sewage smell. Width 60 cm, depth 10 cm, flow 1.872 m/s. Freshwater sample.
76	21/09/11	11:10	NN 02733 78383	202733	778383			6 sheep and droppings
77	21/09/11	11:13	NN 02798 78390	202798	778390		LEW32	Stream. Width 70 cm, depth 32 cm, flow 1.202 m/s. Freshwater sample.

No.	Date	Time	NGR	Easting	Northing	Associated photograph	Sample	Description
78	21/09/11	11:21	NN 02995 78373	202995	778373		LEW33	Stream. Width 70 cm, depth 33 cm, flow 1.995 m/s. Freshwater sample.
79	21/09/11	11:30	NN 03268 78353	203268	778353		LEW 34	Stream through culvert. Width 60 cm, depth 8 cm, flow 1.752 m/s. Freshwater sample.
80	21/09/11	11:36	NN 03346 78338	203346	778338			Very small stream. Not sampled or measured.
81	21/09/11	11:38	NN 03387 78343	203387	778343		LEW35	Culverted stream. Width 60 cm, depth 25 cm, flow 3.684 m/s. Freshwater sample. Approx 15 sheep and droppings on foreshore.
82	21/09/11	11:49	NN 03643 78352	203643	778352		LEW36	Culverted stream. Width 2.45 m, depth 25 cm, flow 1.206 m/s. Freshwater sample.
83	21/09/11	12:03	NN 03852 78361	203852	778361		LEW37	Culverted stream. Width 60 cm, depth 17 cm, flow 0.842 m/s. Freshwater sample. Photograph towards mussel farm.
84	21/09/11	12:08	NN 03865 78364	203865	778364	Figure 13	LEW38	Piped flow through wall. ?smell. Freshwater sample but no measurements
85	21/09/11	12:15	NN 03977 78365	203977	778365		LEW39	Burn. Width 4.60 m, depth 60 cm, flow 1.753 m/s. Freshwater sample.
86	22/09/11	08:13	NN 03079 78395	203079	778395			Deciduous woodland by shore. Coniferous forest above road.
87	22/09/11	08:15	NN 02238 78888	202238	778888			Fassfern Estate. 12 sheep in field.
88	22/09/11	08:18	NN 01621 78425	201621	778425			New build homes. 8 completed, four more in progress.
89	22/09/11	08:22	NN 01204 78414	201204	778414			Approx 26 sheep in field Rough grassland.
90	22/09/11	08:24	NN 00575 78530	200575	778530			Approx 60 sheep in field.

No.	Date	Time	NGR	Easting	Northing	Associated photograph	Sample	Description
91	22/09/11	08:32	NN 00190 78560	200190	778560			Approx 40 sheep in field.
92	22/09/11	08:53	NM 99148 78722	199148	778722			Deciduous woodland by shore. Heather and rough grass above road.
93	22/09/11	08:59	NM 98196 78890	198196	778890			Approx 12 sheep on hillside.
94	22/09/11	09:02	NM 98366 78862	198366	778862			3 sheep in field by shore.
95	22/09/11	09:03	NM 97740 79129	197740	779129			1 horse, 1 pony and 1 sheep in field.
96	22/09/11	09:05	NM 97634 79158	197634	779158			4 sheep above house.
97	22/09/11	09:10	NM 96295 78697	196295	778697			Worked forest.
98	22/09/11	09:12	NM 97059 78476	197059	778476			Converted lifeboat, small motorboat and small open boat moored offshore.
99	22/09/11	09:16	NM 98745 77716	198745	777716			Farm buildings on hill side of road. 6 cattle.
100	22/09/11	09:19	NN 00350 77413	200350	777413			7 sheep on hill side of road. Rough grassland.
101	22/09/11	09:35	NN 00735 77246	200735	777246			Entrance to landfill site.
102	22/09/11	09:38	NN 01196 76997	201196	776997			8 highland cows in field above road.
103	22/09/11	09:42	NN 02866 76954	202866	776954			10 sheep in rough field above road. Also empty sheep pens. Caravan nearby on shore side of road - looks permanent.

No.	Date	Time	NGR	Easting	Northing	Associated photograph	Sample	Description
104	22/09/11	09:45	NN 03319 77053	203319	777053			Permanent caravan on hill side of road – several houses nearby.
105	22/09/11	09:46	NN 03437 77044	203437	777044			Permanent caravan on hill side of road.
106	22/09/11	09:47	NN 03845 77101	203845	777101			4 sheep on shore side of road.
107	22/09/11	09:47	NN 04097 77111	204097	777111			6 sheep on hill side of road.
108	22/09/11	09:48	NN 04360 77193	204360	777193			11 sheep in field on hill side of road.
109	22/09/11	09:49	NN 04582 77217	204582	777217			Permanent caravan on hill side of road.
110	22/09/11	09:51	NN 05117 77084	205117	777084			Approx 6 sheep on shore.
111	22/09/11	09:51	NN 05276 77122	205276	777122			8 sheep in field on hill side of road.
112	22/09/11	09:53	NN 05546 77155	205546	777155			9 sheep in field on hill side of road.
113	22/09/11	10:10	NM 99552 78670	199552	778670			Approx 6 sheep on hillside.
114	22/09/11	10:17	NN 07901 77015	207901	777015			Industrial estate.

Photos referenced in the table can be found attached as Figures 6-13.

Sampling

Water and shellfish samples were collected at sites marked on the maps given in Figures 3, 4 and 5. Bacteriology results are presented in Tables 3 and 4. All samples were received by the laboratory within 24 hours of collection and the temperature at the time of receipt ranged from 4.0 to 6.1°C. Samples of seawater were tested for salinity by the laboratory using a salinity meter under more controlled conditions. These results are shown in Table 3, given in units of grams salt per litre of water. This is the same as ppt.

Table 3. Water Sample Results

No.	Date	Sample	Grid Reference	Type	E. coli (cfu/100ml)	Salinity (g/L)
1	19/09/11	LEW01	NM 9919 7781	Sea	15	20.2
2	19/09/11	LEW02	NM 9898 7799	Sea	7	20.9
3	19/09/11	LEW03	NN 0031 7759	Sea	22	21.3
4	19/09/11	LEW04	NN 0053 7760	Sea	24	21.1
5	19/09/11	LEW05	NN 0293 7788	Sea	12	22.2
6	19/09/11	LEW06	NN 0379 7815	Sea	17	22.7
7	19/09/11	LEW07	NN 0598 7730	Sea	15	21.6
8	20/09/11	LEW08	NM 9593 7913	Fresh	<100	
9	20/09/11	LEW09	NM 9616 7879	Fresh	<100	
10	20/09/11	LEW10	NN 0110 7699	Fresh	<100	
11	20/09/11	LEW11	NN 0094 7722	Fresh	200	
12	20/09/11	LEW12	NN 0056 7737	Fresh	300	
13	20/09/11	LEW13	NN 0038 7744	Fresh	<100	
14	20/09/11	LEW14	NN 0021 7745	Fresh	<100	
15	20/09/11	LEW15	NM 9979 7759	Fresh	<100	
16	20/09/11	LEW16	NM 9962 7765	Sea	22	23.8
17	20/09/11	LEW17	NM 9919 7768	Fresh	<100	
18	20/09/11	LEW18	NM 9900 7771	Fresh	<100	
19	20/09/11	LEW19	NM 9880 7773	Fresh	<100	
20	20/09/11	LEW20	NM 9796 7774	Fresh	<100	
21	21/09/11	LEW21	NN 0717 7697	Sea	68	14.2
22	21/09/11	LEW22	NN 0716 7668	Sea	300	7.7
23	21/09/11	LEW23	NN 0633 7710	Fresh	3100	
24	21/09/11	LEW24	NN 0623 7716	Fresh	2500	
25	21/09/11	LEW25	NN 0598 7723	Fresh	1500	
26	21/09/11	LEW26	NN 0589 7725	Fresh	700	
27	21/09/11	LEW27	NN 0557 7718	Fresh	3100	
28	21/09/11	LEW28	NN 0217 7822	Sea	77	14.8
29	21/09/11	LEW29	NN 0226 7842	Fresh	900	
30	21/09/11	LEW30	NN 0238 7843	Fresh	2200	
31	21/09/11	LEW31	NN 0268 7840	Fresh	2000	
32	21/09/11	LEW32	NN 0280 7839	Fresh	6200	
33	21/09/11	LEW33	NN 0300 7837	Fresh	4900	
34	21/09/11	LEW34	NN 0327 7835	Fresh	2300	
35	21/09/11	LEW35	NN 0339 7834	Fresh	1200	
36	21/09/11	LEW36	NN 0364 7835	Fresh	2500	
37	21/09/11	LEW37	NN 0385 7836	Fresh	6700	

No.	Date	Sample	Grid Reference	Type	E. coli (cfu/100ml)	Salinity (g/L)
38	21/09/11	LEW38	NN 0387 7836	Fresh	34000	
39	21/09/11	LEW39	NN 0398 7837	Fresh	700	

Table 4. Shellfish Sample Results

No.	Date	Sample	Grid Reference	Type	E. coli (MPN/100g)
1	19/09/11	LEM1	NM 9919 7781	Mussel (2-3 m)	310
2	19/09/11	LEM2	NM 9898 7799	Mussel (top)	790
3	19/09/11	LEM3	NM 9898 7799	Mussel (10 m)	330
4	19/09/11	CLASS1*	NN 0031 7759	Mussel (2-3 m)	2400
5	19/09/11	LEM4	NN 0053 7760	Mussel (2-3 m)	330
6	19/09/11	LEM5	NN 0293 7788	Mussel (2-3 m)	2400
7	19/09/11	CLASS2*	NN 0379 7815	Mussel (2-3 m)	1700
8	19/09/11	CLASS3*	NN 0598 7730	Mussel (2-3 m)	2400

*Classification samples taken during the survey and submitted to Veromara for testing

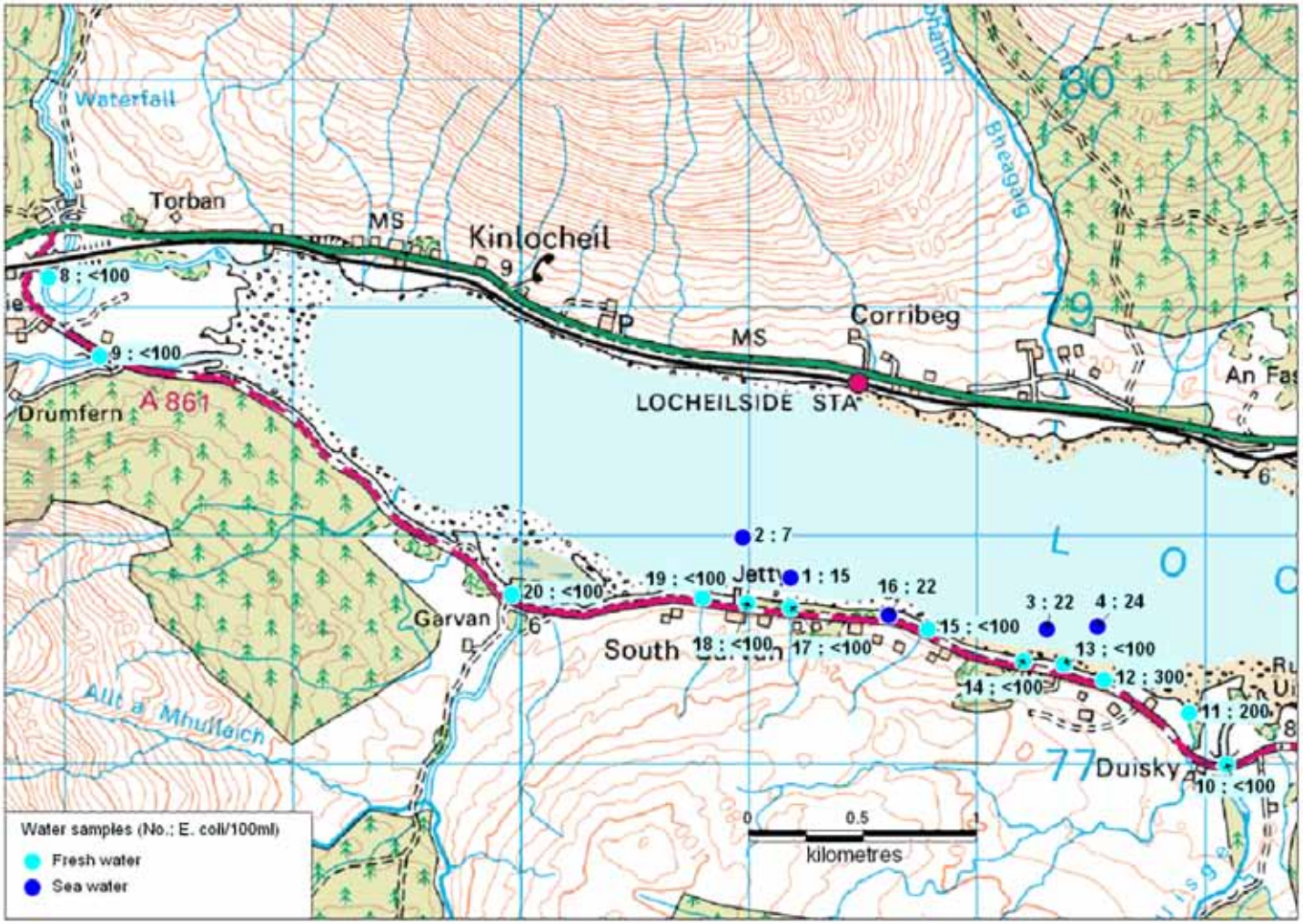

Figure 3. Water sample results map: West

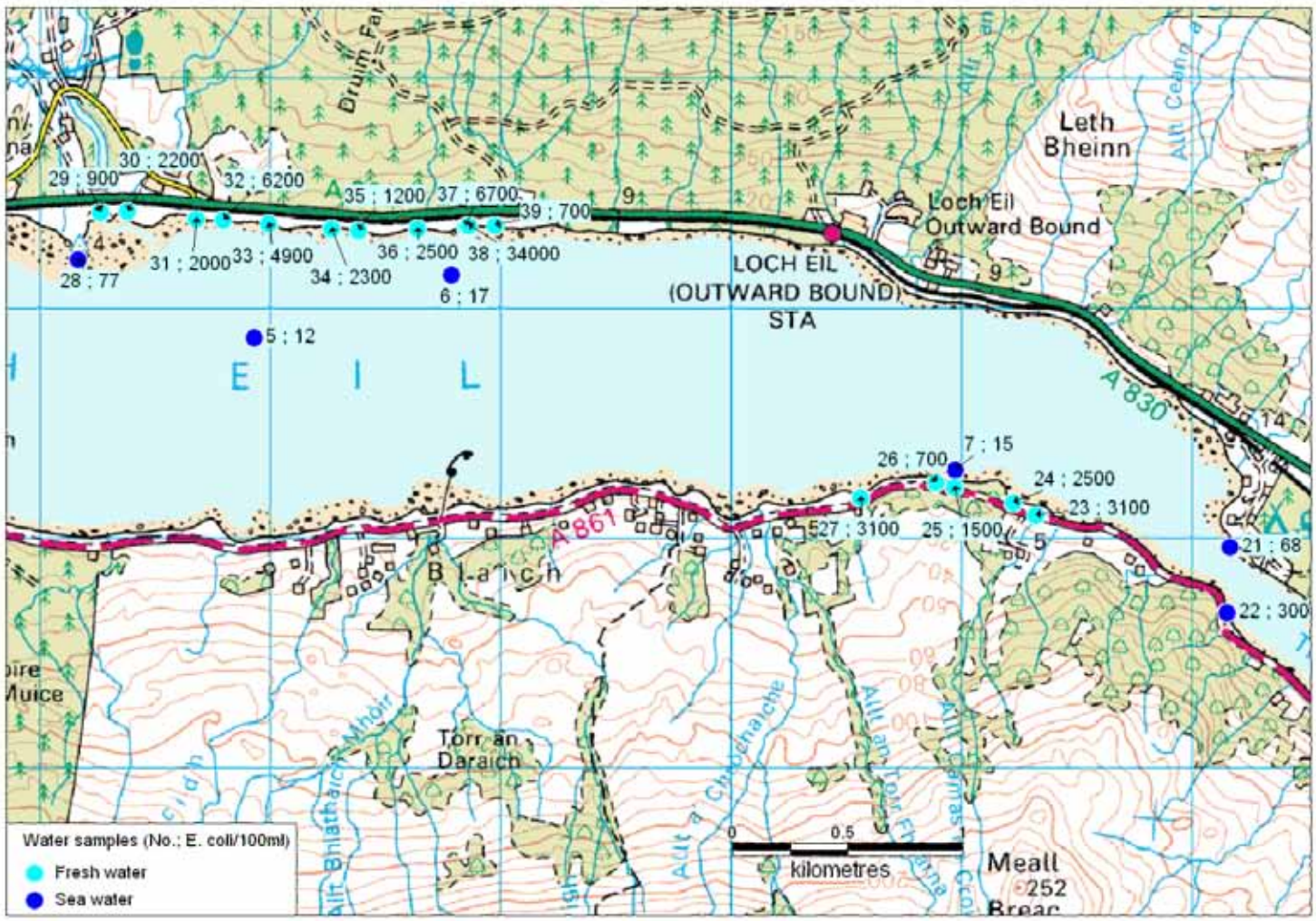

Figure 4. Water sample results map: East

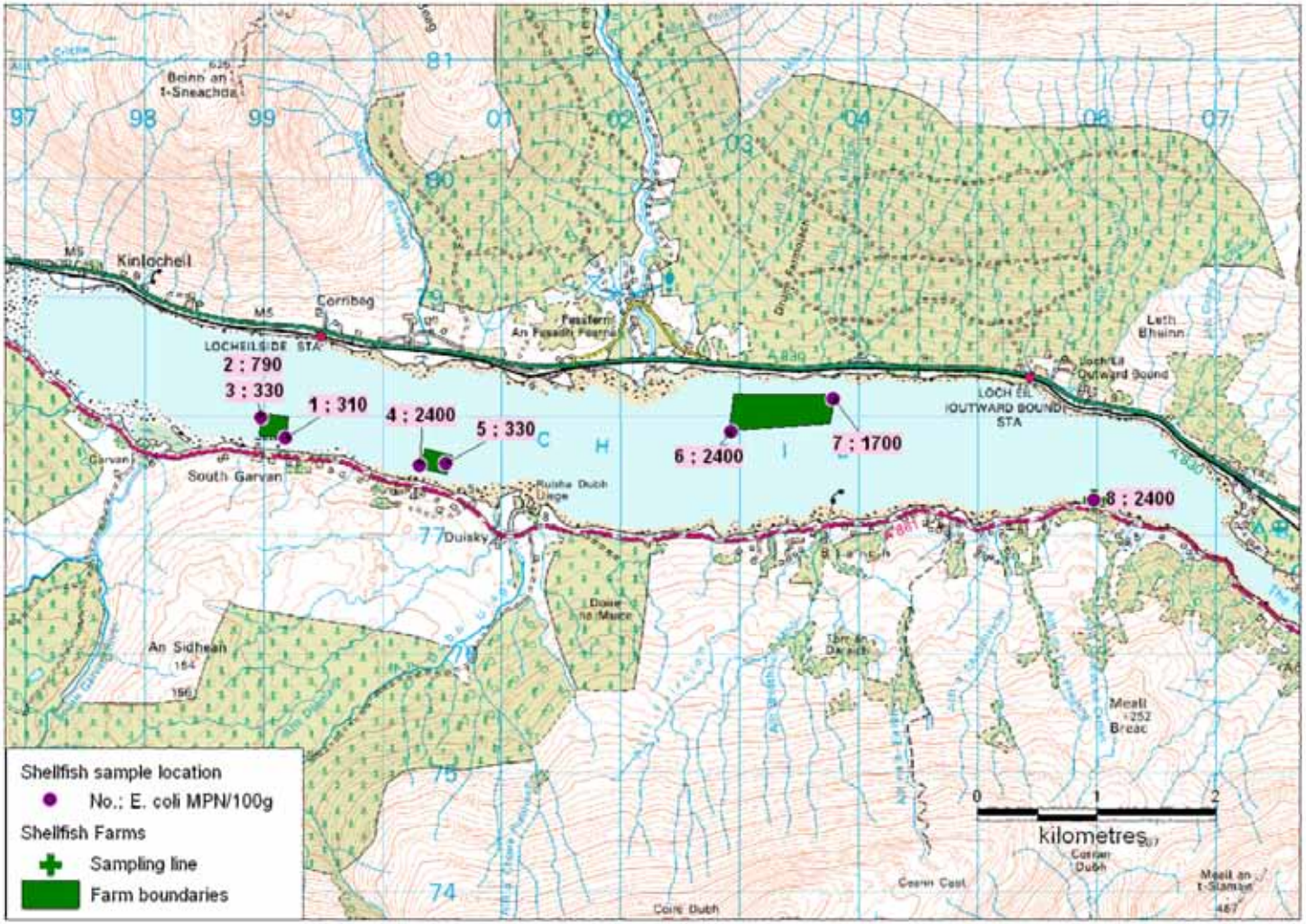

Figure 5. Shellfish sample results map

Photographs

Figure 6. Work base on raft at Duisky site

Figure 7. Fionn Lighe

Figure 8. Dubh Lighe

Figure 9. Gulls on shore, water and floats at Duisky

Figure 10. Garvan River

Figure 11. Culverted burn

Figure 12. River by rail bridge

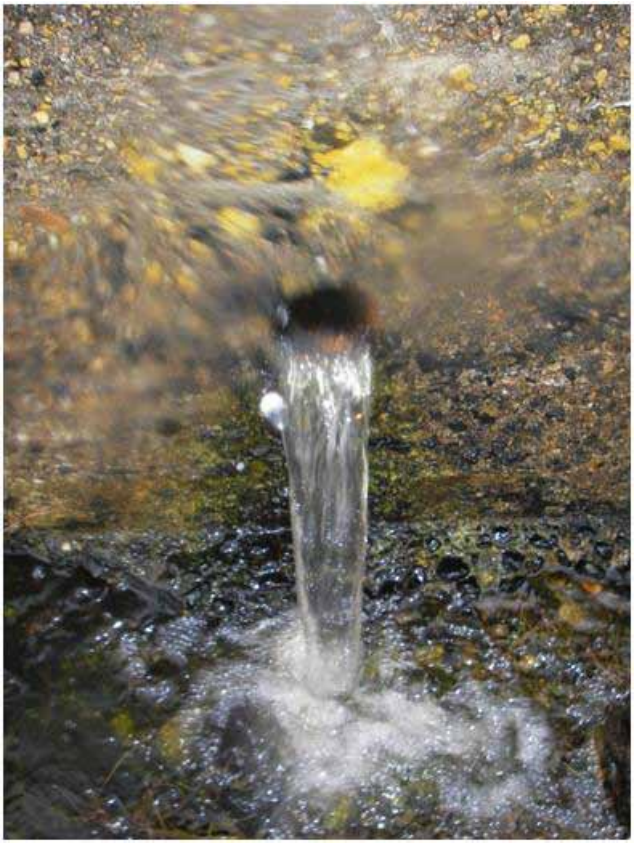

Figure 13. Piped flow from sea wall