Scottish Sanitary Survey Report

Sanitary Survey Report
Loch Eishort
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Centre for Environment, Fisheries & Aquaculture Science, Weymouth Laboratory, Barrack Road, The Nothe, Weymouth DT4 8UB. Tel 01305 206 600 www.cefas.defra.gov.uk

Report Distribution – Loch Eishort

Date	Name	Agency
	Joyce Carr	Scottish Government
	David Denoon	SEPA
	Douglas Sinclair	SEPA
	Hazel MacLeod	SEPA
	Fiona Garner	Scottish Water
	Alex Adrian	Crown Estate
	Alan Yates	Highland Council
	Allan MacDonald	Highland Council
	Peter MacAskill	Harvester
	Robert Kelly	Harvester

Partner Organisations

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

Table of Contents

Appendices

I. Executive Summary

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

The purpose of the sanitary survey is to demonstrate compliance with the requirements stated in Annex II (Chapter II Paragraph 6) of Regulation (EC) 854/2004. The sanitary survey results in recommendations on the location of RMPs, the frequency of sampling for microbiological monitoring, and the boundaries of the production areas deemed to be represented by the RMPs. A sanitary survey was undertaken on the classified mussel fishery at Loch Eishort on the basis recommended in the European Union Reference Laboratory publication: "Microbiological Monitoring of Bivalve Mollusc Harvesting Area Guide to Good Practice: Technical Application" (http://www.cefas.defra.gov.uk/nrl/information-centre/eu-good-practice-guide.aspx). This areas was selected for survey at this time based on a risk-based ranking amongst those Scottish production areas that had yet to receive a survey.

Loch Eishort is a sea loch on the south west coast of the Isle of Skye, off the west coast of Scotland. The loch is bounded by the Sleat peninsula to the south, while to the north lies Loch Slapin.

The classified production area is comprised of two long-line mussel farms located near the head of the loch: Site 1 North (Drumfearn) and Morsaig. The two sites are owned by different harvesters. Much of the *E. coli* monitoring history has been attributed to an RMP that does not lie on either of the active fisheries, and therefore it was not possible to draw conclusions regarding the spatial distribution of results in relation to the shellfish farms

Faecal contamination sources, aside from diffuse contamination arising from wildlife such as seabirds and seals, are concentrated around Heaste and Drumfearn. There is likely to be a greater overall input to the loch at Heaste. However, Drumfearn lies much closer to the shellfish farms and therefore any contamination arising from this area may be more likely to impact on the water quality at the shellfishery.

There have been episodic results > 230 *E. coli* MPN/100 g, including one result >4600. Results since 2013 have been largely below the limit of detection, though it is not clear whether this is due to changes in sampling locations or other factors. Overall, contamination levels at the mussel farms are likely to be low.

The predicted contaminant transport distance is relatively low and therefore it is likely that only sources nearer the mussel farms will significantly impact on water quality ay those locations.

Although there was no statistically significant correlation between season and results, highest results occurred during the months of July, August and October suggesting some seasonal variation in results.

It is recommended that the production area boundaries be curtailed to reflect the location of the farms and to exclude identified sources of faecal contamination around Heaste and at the head of the loch. It is further recommended that the RMP moved to the northwestern end of Site 1 North. Further details of the recommendations can be found in the Sampling Plan and in Section 17 of this report.

II. Sampling Plan

Production Area	Loch Eishort
Site Name	Site 1 North (Drumfearn)
SIN	SL-137-281-08
Species	Common mussels
Type of Fishery	Long line
NGR of RMP	NG 6644 1628
East	166440
North	816280
Tolerance (m)	40
Depth (m)	1-3 m
Method of Sampling	Hand
Frequency of Sampling	Monthly
Local Authority	Highland Council Skye & Lochaber
Authorised Sampler(s)	Allan MacDonald
Recommended Production Area	The area bounded by lines drawn from NG 6704 1669 to NG 6716 1651 and from NG 6569 1615 to NG 6569 1531 and extending to MHWS

III. Report

1. General Description

Loch Eishort is a sea loch on the southwest coast of the Isle of Skye, off the west coast of Scotland. The loch is bounded by the Sleat peninsula to the south. Loch Eishort lies within the Skye and Lochalsh district of the Highland Council.

The area around Loch Eishort is sparsely inhabited with the small settlements of Heaste on the north shore and Drumfearn and Ord on the south shore. The land around the loch is steeply hilly, particularly along the south shore.

Loch Eishort is approximately 10 km in length and has a width of approximately 600 m at the fisheries: the width at the mouth is 3.6 km. It has a maximum recorded depth of 38 m. It has a mainly east-west aspect, with the mouth opening to the WSW where it meets Loch Slapin.

This sanitary survey was undertaken on the classified fishery at Loch Eishort on the basis recommended in the European Union Reference Laboratory publication: “Microbiological Monitoring of Bivalve Mollusc Harvesting Area Guide to Good Practice: Technical Application” (http://www.cefas.defra.gov.uk/nrl/information-centre/eu-good-practice-guide.aspx). This production area was selected for survey at this time based on a risk-based ranking of the area amongst those in Scotland that have yet to receive sanitary surveys.

Figure 1.1 Location of Loch Eishort

2. Fishery

The fishery at Loch Eishort is a common mussel (*Mytilus edulis*) fishery which has been classified for production at least since 2001. Details of the sites within the production area are given in Table 2.1.

Table 2.1 Area shellfish farms

Production area	Site	SIN	Species	Owner	Nominal RMP
Loch Eishort	Drumfearn (Site 1 North)	SL-137-281-08	Common mussels	P. MacAskill	NG 6641 1614
	Morsaig	Not assigned	Common mussels	R. Kelly	

The production area is defined as the area east of a line drawn between NG 6400 1575 and NG 6400 1507 extending to MHWS.

The shoreline survey identified two sites: Drumfearn, along the north shore of the loch (identified by the harvester as Site 1 North) and Morsaig, along the south shore.

At the time of shoreline survey, Site 1 North consisted two separate blocks totalling 17 long lines, all with 7 m droppers. This area was recorded as one large block for the purposes of geographic representation. The Morsaig site consisted of six long lines with 7 m droppers.

The nominal RMP (as taken from the most recent FSAS RMP list) plots at a location approximately 120 m south of the northwest extent of the recorded mussel farm. The observed RMP recorded during the shoreline survey was identified as NG 6653 1633, which lies within the western half of Site 1 North.

The locations of the mussel farms, production area boundaries and monitoring points are shown in Figure 2.1.

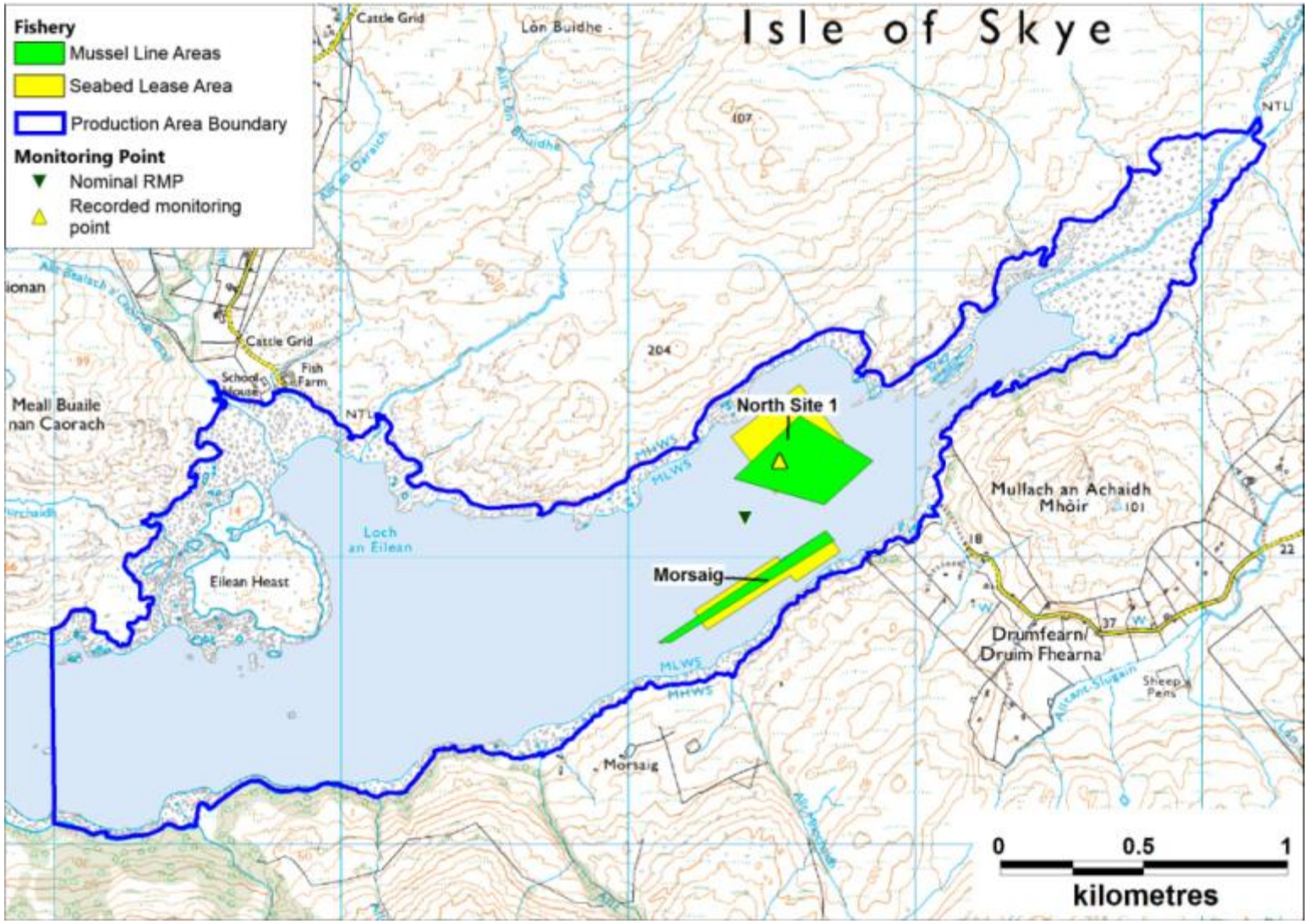


Figure 2.1 Loch Eishort Fishery

3. Human Population

Information was obtained from the General Register Office for Scotland on the population within the vicinity of Loch Eishort production area. The last census was undertaken in 2011. The census output areas surrounding Loch Eishort are shown thematically mapped by the 2011 population densities in Figure 3.1. The population density is low (< 4 people per km^2) in the census output areas adjoining the loch.

Table 3.1 Population by census output area for Loch Eishort

Census output area	Size (km^2)	Population
S00081090	47.4	124
S00081109	19.3	73
S00081104	52.1	132
S00081141	82.4	97

The crofting townships of Heaste and Drumfearn are located along the north shore and south shore of the loch, respectively. The townships are accessed via minor roads from the A851 or A87, and provide the only road access to the shores of the loch. The remainder of the shoreline is uninhabited and only accessible by foot. There is tourist accommodation in the area, including B&B and caravan accommodation in Heaste and B&B accommodation in Drumfearn.

During the shoreline survey approximately 25 private dwellings were observed on the north side of the loch: two of these dwellings were close to the shoreline. At Drumfearn, four private dwellings were observed on the hillside south of the loch. No campsites or obvious tourist facilities were observed.

There is a single anchorage located east of Eilean Heast (Clyde Cruising Club, 2007). A floating jetty was observed at Heaste and six fishing boats and one pleasure boat were seen on the water.

Overall, impacts from human sources to the water quality at the mussel farms are likely to be low to moderate due to the low population density in the area. Drumfearn lies closest to the mussel farms. Any impact from visiting boats is most likely to affect the area around Heaste which lies approximately 1.5 km west of the fishery.

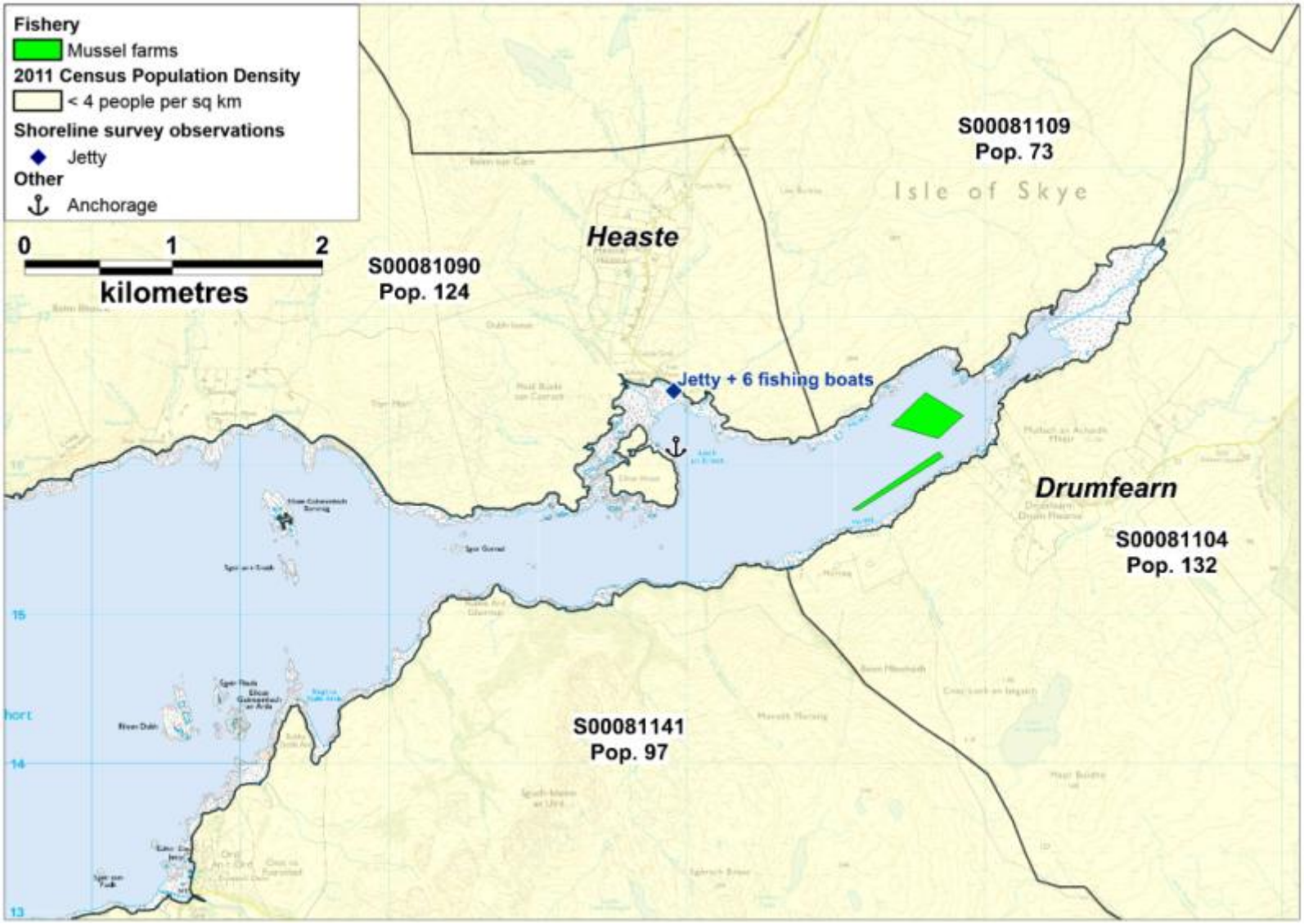


Figure 3.1 Population map for the area in the vicinity of Loch Eishort

4. Sewage Discharges

Data relating to sewage discharges within an area 7.5 km around the point NG 66410 16140 (between the two mussel farms) was requested from Scottish Water and the Scottish Environment Protection Agency (SEPA). Data requested included the name, location, type, size (in either flow or population equivalent), level of treatment, sanitary or bacteriological data, spill frequency, discharge destination (to land, watercourse or sea), any available dispersion or dilution modelling studies, and whether improvements were in work or planned. Summary information was provided by both agencies.

4.1 Community Discharges

SEPA reported no community discharges in the area covered by the request. While Scottish Water provided information on some community outfalls, these discharged to the northwest coast of Skye so have been excluded from this assessment as they were considered to be unlikely to impact on water quality on the southeast coast.

4.2 Consented Private Discharges - SEPA

SEPA provided information on 43 consented discharges within the request area identified. Discharges relating to abstraction or engineering works were excluded from assessment, as they are not expected to contribute any faecal input to the area. The discharges of greatest relevance to the mussel farm are listed in Table 3.1 below and labelled on the map in Figure 4.1.

Table 3.1 Population by census output area for Loch Eishort

No.	Licence	Description	NGR	PE	Discharges to
1	CAR/R/1034330	Septic tank effluent	NG 65002 17729	10	Allt an Daraich
2	CAR/R/1055913	Septic tank effluent	NG 64905 17694	5	Soakaway
3	CAR/R/1056016	Septic tank effluent	NG 64860 17650	5	Soakaway
4	CAR/R/1045317	Septic tank effluent	NG 64740 17610	6	Soakaway
5	CAR/R/1085702	Septic tank effluent	NG 64730 17460	5	Soakaway
6	CAR/R/1070099	Septic tank effluent	NG 64800 17330	8	Soakaway
7	CAR/R/1048888	Septic tank effluent	NG 64770 17075	5	Land
8	CAR/R/1078398	Septic tank effluent	NG 64623 16982	10	Soakaway
9	CAR/R/1078936	Septic tank effluent	NG 64612 16916	5	Soakaway
10	CAR/R/1048717	Septic tank effluent	NG 67064 16143	5	Loch Eishort

All consented discharges assessed in this report are listed in Appendix 7 and are shown in Figure 4.1. Only one discharge (CAR/R/1048717) lies within 2 km of the nearest mussel lines. This is a relatively small septic tank with a PE of 5.

Eight discharges in the settlement of Drumfearn were excluded from this assessment as they discharge into the catchment of Alltant Slugain, which flows into Loch na Dal on the south coast of Skye, so are considered unlikely to impact on the production area. The boundary between the catchments was estimated using the countours and watercourses shown on the OS 1:25000 raster base map. The consents that have been excluded, as well as the estimated boundary, are shown for reference in Figure 4.1.

A number of consents related to discharges around Ord, on the south shore of the outer part of Loch Eishort. Three of these consents were for discharges to the loch itself. Whilst nearly all the consents were for individual homes, one was for a septic tank serving a group of 10 cabins to the north of Ord and had a PE of 50. These discharges all lie at least 5 km southwest of the mussel farms.

The large majority of the identified septic tanks are consented to discharge to soakaway. Three of the discharge locations at Ord plot at or below the mean high water mark. The effectiveness of soakaway systems depends on location and maintenance. SEPA have identified previously that in remote areas, consents originally registered as discharging to land may have been diverted to sea or to watercourses upon failure of the soakaway fields.

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

Shoreline Survey Discharge Observations

No observations of sewage effluent or infrastructure were recorded during the shoreline survey.

Summary

As there are no community discharges to the area, the primary inputs come from small private discharges. These are concentrated around Heaste and Ord: the latter include the septic tanks with the largest consented PEs, although those at Ord lie more than 5 km from the mussel farms. There is a single consented discharge to sea at Drumfearn, approximately 300 m southeast of the southern end of Site 1 North. Septic tanks at Heaste that may discharge to Allt an Oaraich, Allt an Daraich and its tributaries may also have an impact though these are over 1.5 km away from the mussel farms.

List of Acronyms

MDF=	Mean daily flow	DWF=	Dry weather flow
PE=	Population Equivalent	ST=	Septic Tank
WWTW=	Wastewater Treatment Work	CSO=	Combined Sewer Overflow

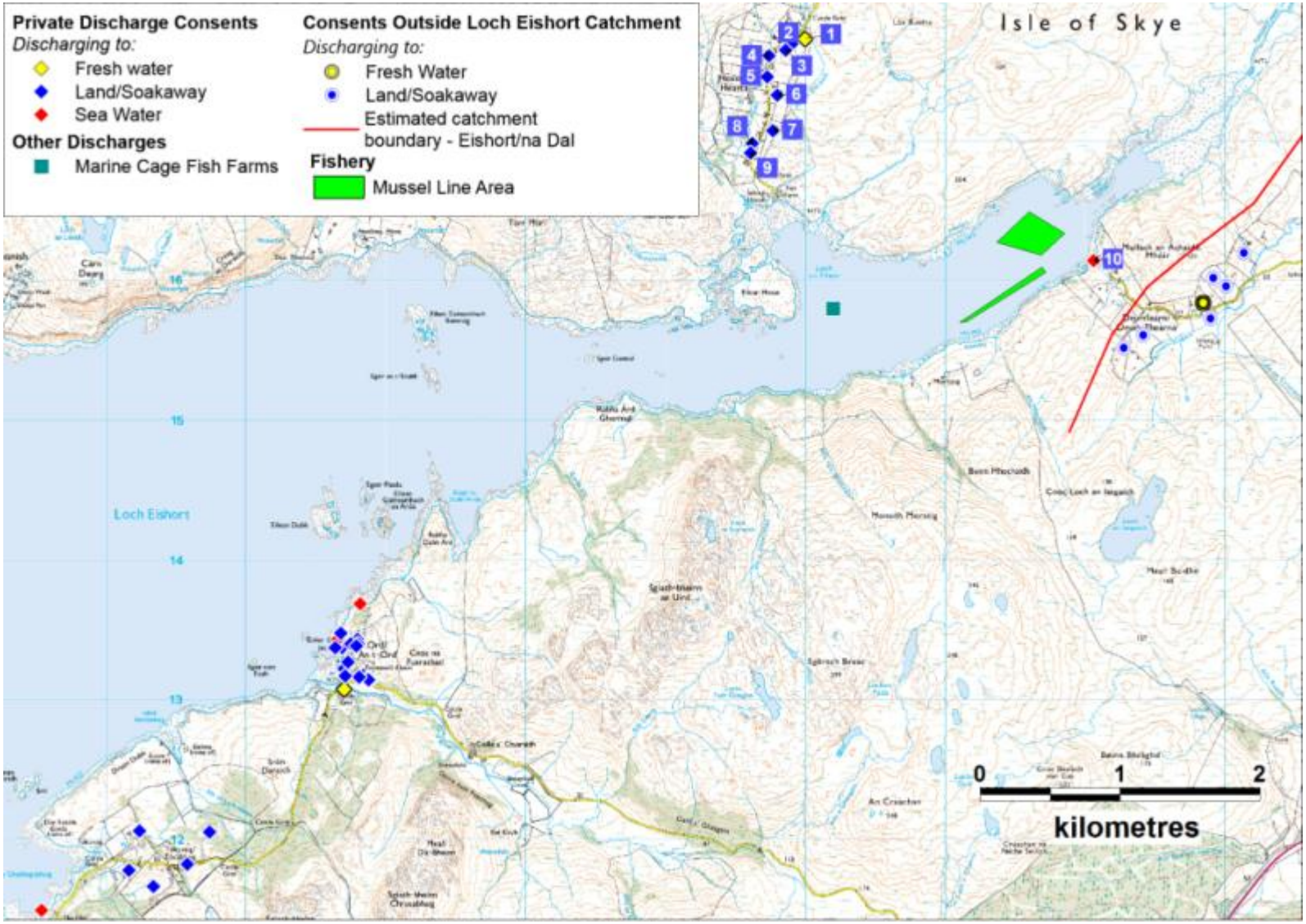


Figure 4.1 Map of discharges for Loch Eishort

5. Agriculture

Information on the spatial distribution of animals on land adjacent to or near the fishery can provide an indication of the potential amount of organic pollution from livestock entering the shellfish farm areas. Agricultural census data to parish level was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for the Strath and Sleat parishes. Reported livestock populations for the parishes in 2013 are listed in Table 5.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reporting would have made it possible to discern individual farm data. Any entries which relate to less than five holdings, or where two or fewer holdings account for 85% or more of the information, are replaced with an asterisk.

Table 5.1 Livestock numbers in the Strath and Sleat agricultural parishes 2013

	Strath		Sleat	
	280 km^2		169 km^2	
	Holdings	Numbers	Holdings	Numbers
Pigs	*	*	7	22
Poultry	22	205	20	223
Cattle	31	522	33	594
Sheep	40	6,919	46	10,055
Other horses and ponies	10	20	11	24

* data withheld

The livestock census numbers for Strath and Sleat relate to very large parish areas, therefore it is not possible to determine the spatial distribution of the livestock on the shoreline adjacent to the loch or to identify how many animals are likely to impact the catchment around the mussel farms. Although the figures are of little use in assessing the potential impact of livestock contamination to the shellfishery they do give an idea of the total numbers of livestock over the broader area. Sheep were kept in large numbers in both parishes, with cattle and poultry kept in modest numbers. There were relatively few pigs and horses reported, though no pig numbers were reported for Strath parish due the small number of holdings.

A source of spatially relevant information on livestock population in the area was the shoreline survey (see Appendix 5) which only relates to the time of the site visit on the 28th April 2014. Observations made during the survey are dependent upon the viewpoint of the observer some animals may have been obscured by the terrain. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 5.1.

During the shoreline survey eight sheep were observed close to a small farm/croft near Drumfearn on the southern side of the loch. Approximately 14 cattle and eight sheep

were observed grazing on the northern shoreline close to Heaste and approximately 15 sheep were also observed on the island of Eilean Heaste.

A review of publicly available aerial images shows that areas of improved pasture are located inland south east of the mussel farms and also inland north of Eilean Heaste (Bing Maps, accessed 10/06/2014). Areas identified from the aerial images as likely improved pasture are shown in Figure 5.1.

Numbers of sheep are expected to be approximately double during the spring and summer months when lambs are present. Any contributions of faecal contamination from livestock grazing in the area would potentially affect those shellfish grown in shallower water closest to the shore. The largest concentration of livestock was observed on the shoreline south of Heaste and on the island of Eilean Heaste. Livestock present along the shore south of the mussel farms and along watercourses draining into the production areas would be expected to have the greatest impact. Based on the distribution of animals seen during the shoreline survey and pasture seen in satellite images, impacts may be expected to be greatest at the southeast end of the Loch Eishort and north of the island of Eilean Heaste.

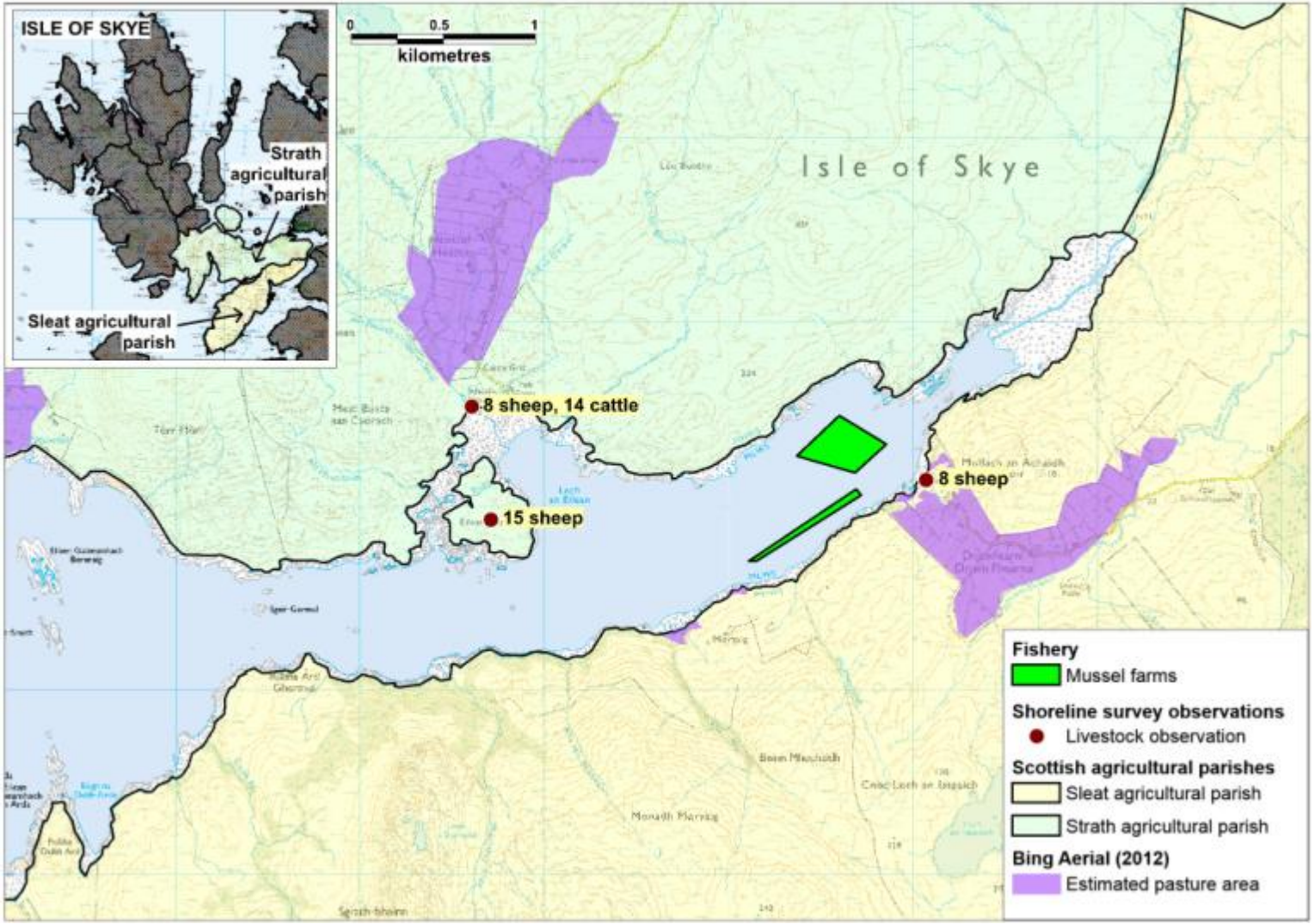


Figure 5.1 Livestock observations at Loch Eishort

6. Wildlife

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

The species most likely to contribute to faecal indicator levels at the Loch Eishort common mussel fishery are considered below.

Pinnipeds

The Special Committee on Seals (SCOS, 2012) have reported that surveys undertaken between 2007 and 2011 showed approximately 100 harbour seals (*Phoca vitulina*) and a small number of grey seals (*Halichoerus grypus*) around Loch Eishort with similar numbers recorded at nearby Loch Slapin. No seals were observed during the shoreline survey.

Cetaceans

The Hebridean Whale and Dolphin Trust have recorded that six unidentified dolphins were observed at Loch Eishort in April 2010 (Hebridean Whale and Dolphin Trust, 2014). The water surrounding the Isle of Skye is however renowned for supporting pods of dolphins, whilst other cetaceans (in particular Minke whales) are also reported to frequent the area, with sightings most common between May to October (IsleofSkye.com, n.d.).

During the shoreline survey a dead, decomposing whale was observed on the north shore at Loch an Eilean.

Birds

Seabird data was downloaded from the collated JNCC dataset from the website (JNCC, 2014) in March 2014. The dataset was then manipulated to show the most recent data where repetitions of counts were present. It should be appreciated that the sources of this data are varied, with some recorded as unknown, or estimated, whilst some come from reliable detailed surveys such as those carried out for the Seabird 2000 report by Mitchell *et al.*, (2004). Data applicable for the 5 km area around the fisheries are listed in Table 6.1.

Table 6.1 Seabird counts within 5 km of Loch Eishort

Common name	Species	Count	Method
Herring Gull	*Larus argentatus*	57	Individuals on sea
Great Black-Backed Gull	*Larus marinus*	4	Individuals on sea
Common Tern	*Sterna hirundo*	10	Individuals on land
Arctic Tern	*Sterna paradisaea*	60	Individuals on land

Two separate counts of birds were identified in the JNCC dataset. These were located at Eilean Dubh and Eilean Gaineamhach Boreraig, located to the southwest of the Loch Eishort fisheries. Observations were of individuals on land or on sea, and therefore it is not clear whether particular species identified have breeding colonies on these two islands. Impacts are expected to be minimal, but the information does indicate that moderate numbers of birds use the loch. Seabirds, particularly those breeding in the area, are likely to be more numerous during the summer breeding season, however no information was found on seasonal variation in these populations in this area. Some species, such as herring gulls, may be present in the area year-round.

There are a number of intertidal areas around the head of the loch, particularly along the mouth of the Abhainn Ceann Loch Eiseoirt and between Eilean Heast and the north shore of Loch an Eilean. These may attract shorebirds in significant numbers, however no specific information on these animals was found for the area. Shorebird numbers are expected to vary seasonally, however no specific information was found on the seasonal populations in the area.

During the shoreline survey, four common gulls and two oystercatchers were observed close to a watercourse adjacent to the southern mussel site. It is anticipated that gulls and other seabirds may directly deposit droppings on or near the fishery as they move about the area and rest on mussel floats.

Deer

The Isle of Skye is noted to support a significantly sized population of Red deer (IsleofSkye.com, n.d.). These animals inhabit hillsides during the summer, and come down to lower land during the winter months and are therefore expected to have a more significant impact on contamination levels during winter months. No deer were observed during the shoreline survey.

Otters

The European otter (*Lutra lutra*) are noted to be found across the Isle of Skye (IsleofSkye.com, n.d.). In particular, the special area of conservation (SAC) at Kinloch and Kyleakin Hills have otters as a designation feature species, which is similarly true for the site of special scientific interest (SSSI) at Kinloch and Kyleakin Hills (Monadh Chaol Acainn is Cheann Loch). No otters were observed during the shoreline survey.

Overall

Wildlife are expected to contribute to background levels of contamination at both sites. Seabirds, in particular, may directly deposit droppings on or near the mussel farms, particularly around the floats. There may be larger numbers of seabirds in the area during the summer breeding season, however no specific information was found on the extent of this variation.

The recorded seabird populations lie over 3.5 km west of the fishery, though birds may use waters over a wider area. Any shorebirds are likely to use intertidal areas around the loch, the largest of which are at the head of the loch (approximately 1 km northeast of Site 1 North) and around Loch an Eilean (approximately 1.5 km northwest of Morsaig). Birds such as gulls and cormorants that use the mussel floats to rest are likely to have the most direct impact to the fishery.

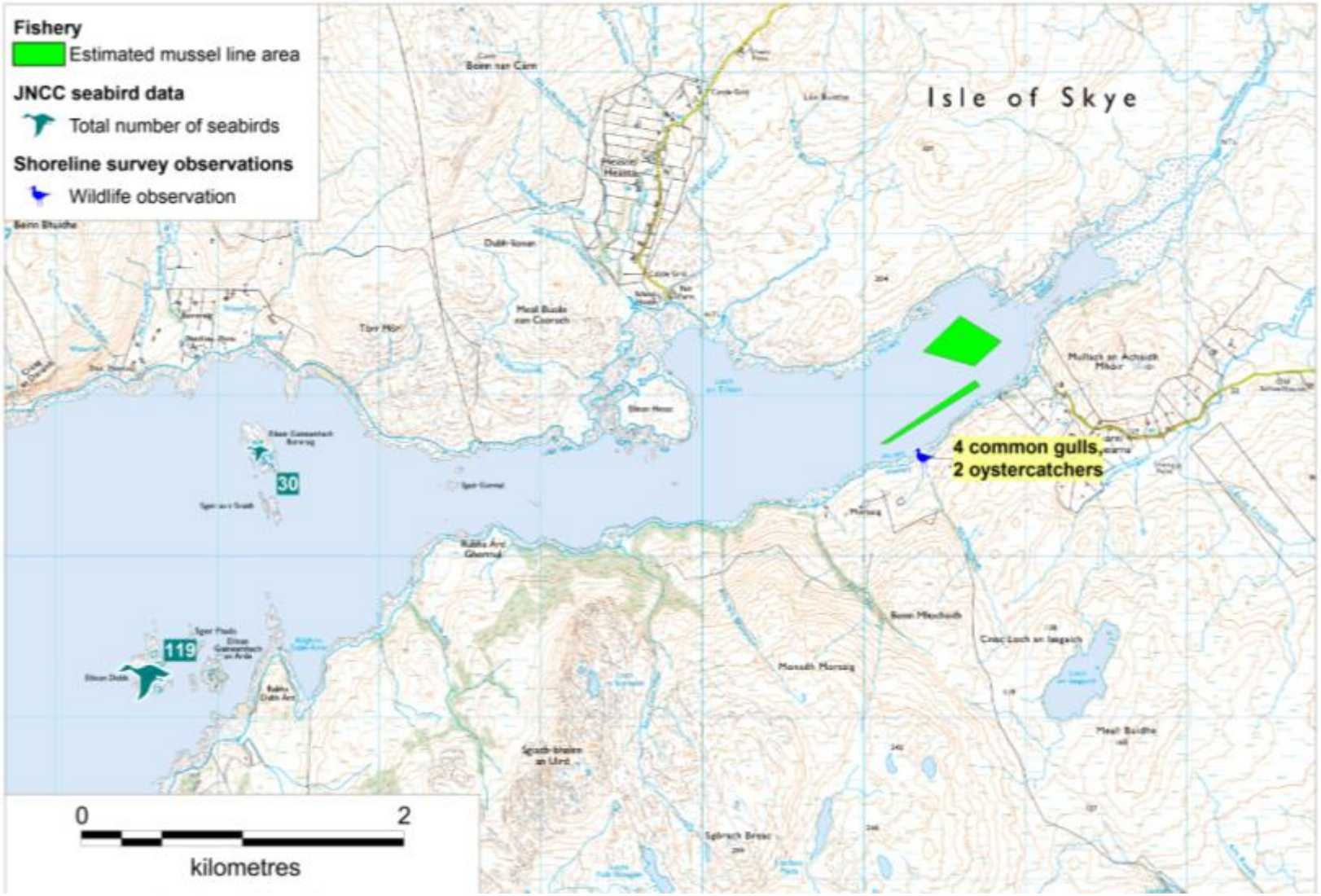


Figure 6.1 Map of wildlife around Loch Eishort

7. Land Cover

The predominant land cover types adjacent to Loch Eishort are dwarf shrub heath, bog, improved grassland and rough grassland. There are also scattered small areas of broadleaved woodland and acid grassland. The areas identified as improved pasture correspond with the crofting townships of Heaste and Drumfearn. There are no built up or urban areas represented. The Land Cover Map 2007 data for the area is shown in Figure 7.1.

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

The areas of improved grassland shown in the land cover data did not match the areas of improved pasture estimated from satellite imagery in Section 5 of this report. In particular, the area of improved grassland shown at Drumfearn is much smaller and further from the shoreline than that given in Section 5. Shoreline observations identified sheep on the areas identified as pasture and for the purposes of this assessment the land adjacent to the shoreline at Drumfearn is considered as improved grassland. Any potential contribution of diffuse faecal contamination attributable to land cover type with therefore be greatest in Loch an Eilean, south of Heaste and along the shore south of the mussel lines at Drumfearn. This contribution would be expected to increase after rainfall events.

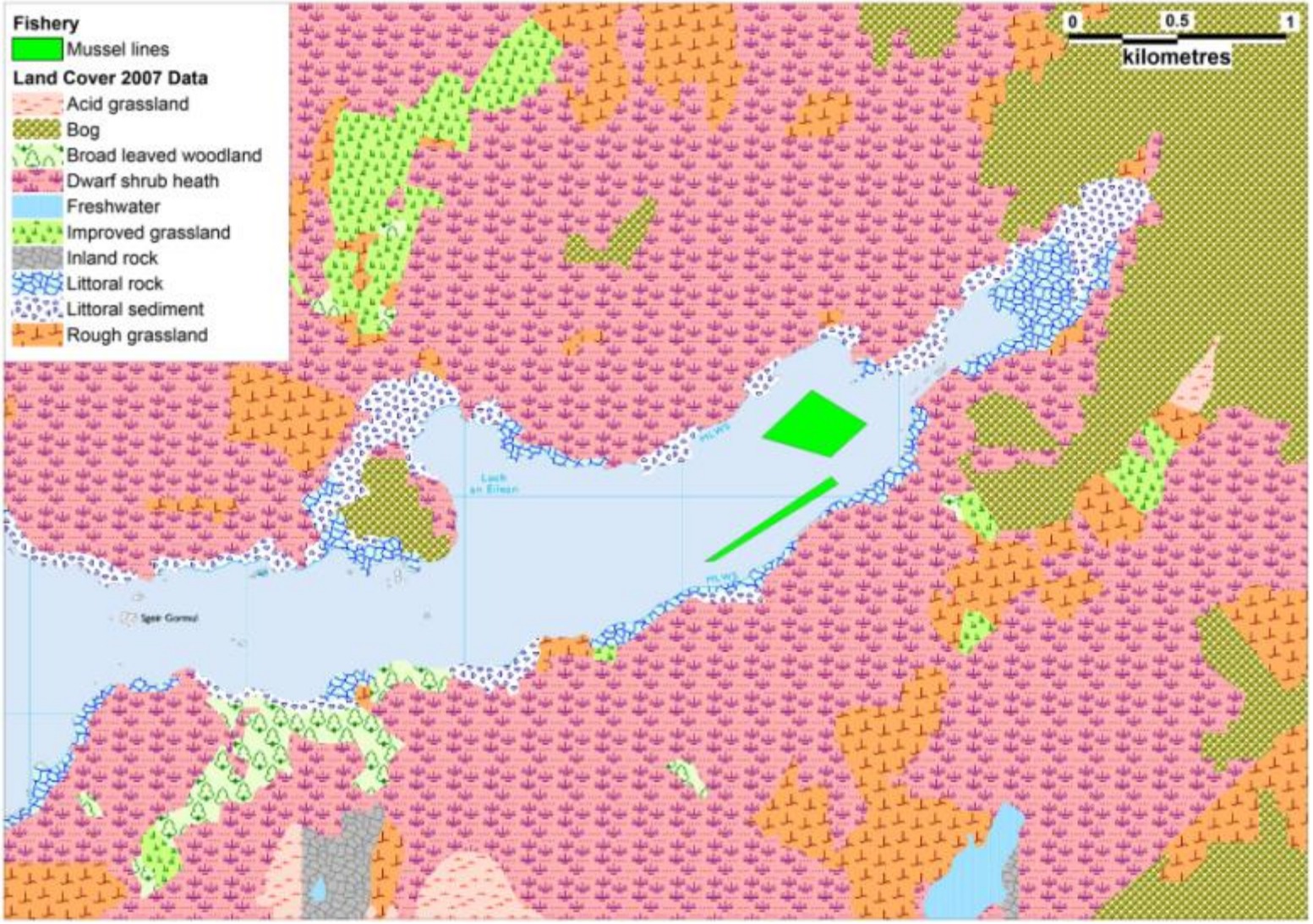


Figure 7.1 LCM2007 land cover data for the area around Loch Eishort

8. Watercourses

There are no gauging stations on watercourses entering Loch Eishort. The largest watercourse discharging to Loch Eishort is Abhainn Ceann Loch Eiseoirt, which discharges to the head of the loch.

Spot measurements of flow and microbial content were obtained during the shoreline survey conducted on the 17th June 2014. No precipitation was recorded in the 48 hrs prior to the survey. The watercourses listed in Table 8.1 are those recorded during the shoreline survey. No areas of land drainage were observed. The locations and loadings of measured watercourses are shown in Figure 8.1.

Table 8.1 Watercourses entering Loch Eishort

No.	Eastings	Northings	Description	Width (m)	Depth (m)	Flow (m^3/d)	Loading (*E. coli* per day)
1	166374	815599	Allt Mhochaidh	2.83	0.12	1203	$< 1.2 \times 10^{8**}$
2	167077	816149	Unnamed watercourse	0.83	0.08*	115*	1.1×10^{8}
3	165136	816462	Allt Lon Bhuidhe	6.26	0.175*	947*	1.2×10^{9}
4	164782	816584	Allt an Daraich	3.27	0.24*	305*	$< 3.1 \times 10^{7**}$
5	164606	816549	Allt na Heaste	7.39	0.225*	7039*	1.4×10^{10}
6	164328	816126	Allt Mhurchaidh	1.03	0.14	249	5×10^{7}

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

Abhainn Ceann Loch Eiseoirt drains an uninhabited area of steep upland. As the river mouth is between 1 and 2 km from the nearest access, it was not sampled for this survey and a seawater sample at the narrows northeast of Site 1 North was taken instead to identify whether significant amounts of faecal contaminants were reaching the fishery from that source. That sample showed no detectable *E. coli*, suggesting that the river was not a significant contributor of faecal contamination at the time of survey.

The two watercourses that flow into the south east corner of the loch adjacent to the shellfish farms, Allt Mhochaidh (watercourse number 1) and watercourse number 2, both had low loadings.

Of the watercourses discharging to Loch an Eilean, south of Heaste, Allt na Heaste (watercourse number 5) had the highest calculated loading. Watercourse 3 had a moderate loading, watercourse 6 had a low loading and the other could not be determined but the upper limit was low.

Overall, freshwater inputs are expected to provide moderate levels of contamination to the mussel farms in Loch Eishort, with the highest impact expected from the watercourses that discharge closest to the shellfish farms on the south east coastline. These watercourses would potentially impact on the lines closest to the southern shoreline. The available information indicates that there would not be a significant effect from the main river at the head of the loch.

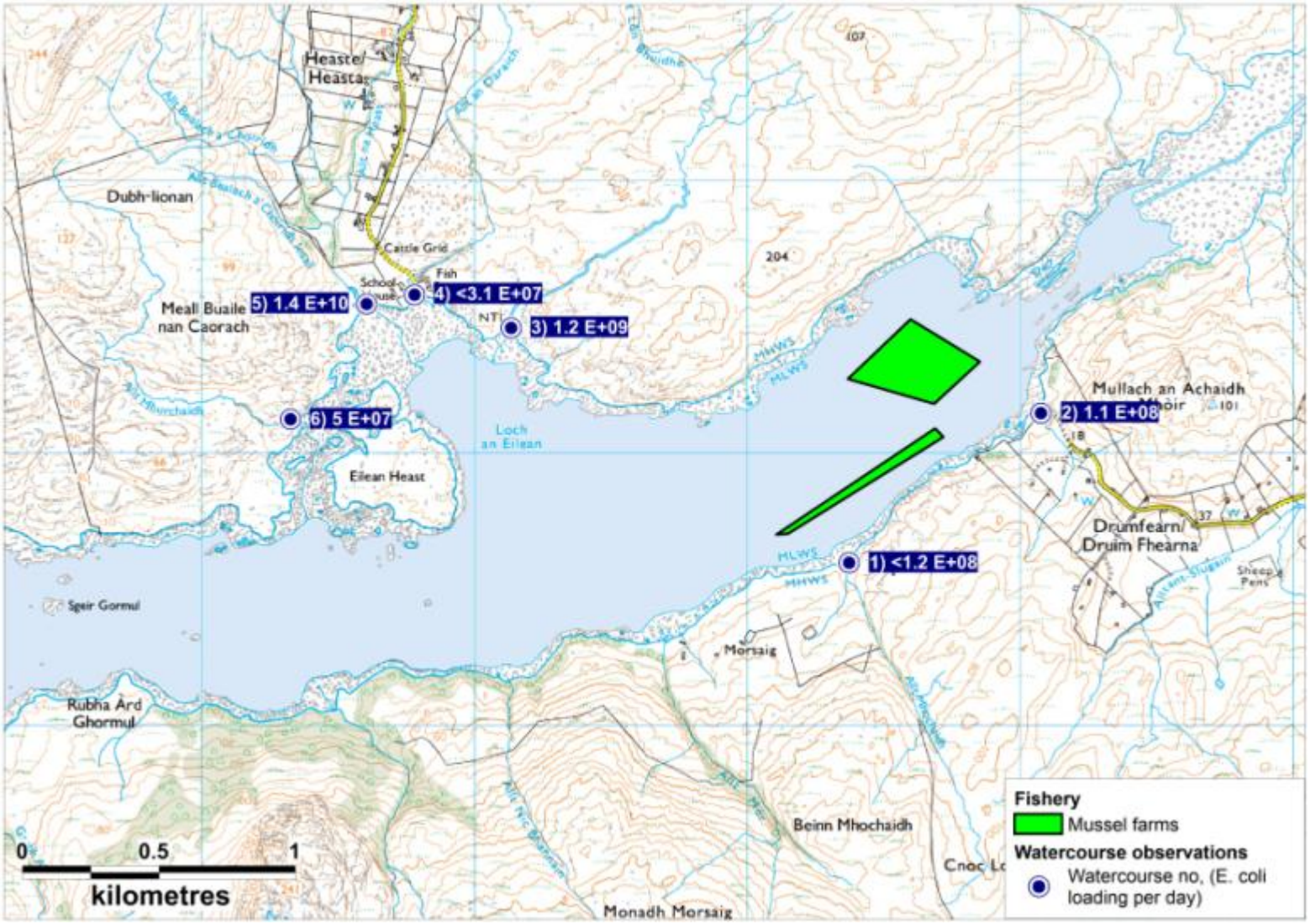


Figure 8.1 Map of watercourse loadings at Loch Eishort

9. Meteorological data

The nearest weather station for which a nearly complete rainfall data set was available is Skye: Lusa, situated approximately 10 km to the north of the production area. Rainfall data was available for January 2008 – December 2013, however data for a total of 32 days in 8 different months were excluded from assessment during validation when they were made up of accumulated or estimated values. Dates excluded by year were: 12 days in 2008, 6 in 2009, 2 in 2010, 8 in 2011 and 4 in 2012.

The nearest wind station is situated at South Uist: Range, located 93 km west of the production area. Conditions may differ between this station and the fisheries due to the distances between them. However, this data is still shown as it can be useful in identifying seasonal variation in wind patterns.

Data for these stations was purchased from the Meteorological Office. Unless otherwise identified, the content of this section (e.g. graphs) is based on further analysis of this data undertaken by Cefas. This section aims to describe the local rain and wind patterns in the context of the bacterial quality of shellfish at Loch Eishort.

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 (Mallin, et al., 2001; Lee & Morgan, 2003). The box and whisker plots in Figures 9.1 and 9.2, present a summary of the distribution of individual daily rainfall values by year and by month. The grey box represents the middle 50% of the observations, with the median at the midline. The whiskers extend to the largest or smallest observations up to 1.5 times the box height above or below the box. Individual observations falling outside the box and whiskers are represented by the symbol *.

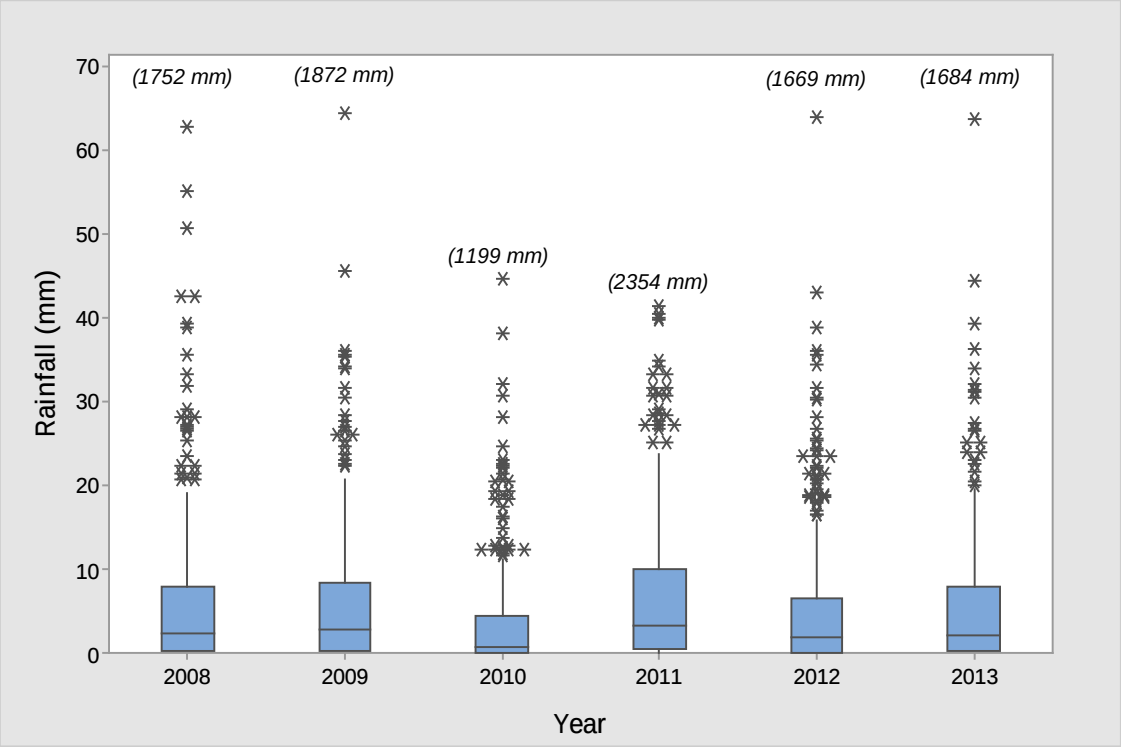


Figure 9.1 Box plot of daily rainfall values by year at Skye: Lusa (2008 – 2013)

Daily rainfall values varied from year to year, with 2010 having the lowest overall daily rainfall and the lowest total rainfall (1199 mm). The wettest year was 2011 (2354 mm). Rainfall values exceeding 40 mm/d occurred in all years, but high rainfall values exceeding 60 mm/d occurred in 2008, 2009, 2012 and 2013.

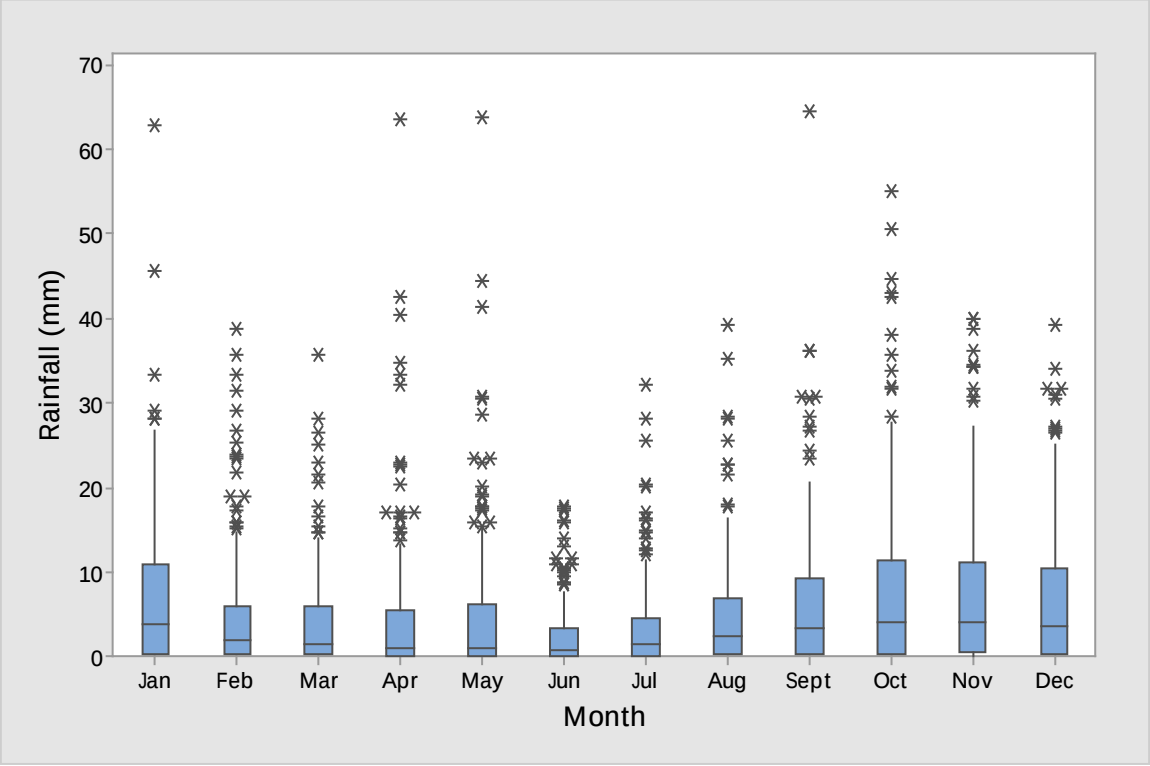


Figure 9.2 Box plot of daily rainfall values by month at Skye: Lusa (2008 – 2013)

Daily rainfall values were higher during the autumn and winter and lower in June and July. Total monthly rainfall was greatest in October (1348 mm) and lowest in June (429 mm). Rainfall values exceeding 30 mm/d occurred in all months except June and exceptionally high rainfall values of 60 mm/d were seen in January, April, May and September.

For the period considered here (2008 – 2013) 40 % of days received daily rainfall of less than 1 mm and 19 % of days received daily rainfall of over 10 mm.

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

9.2 Wind

Wind data was collected from South Uist: Range and summarised in seasonal wind roses in Figure 9.3 and annually in Figure 9.4.

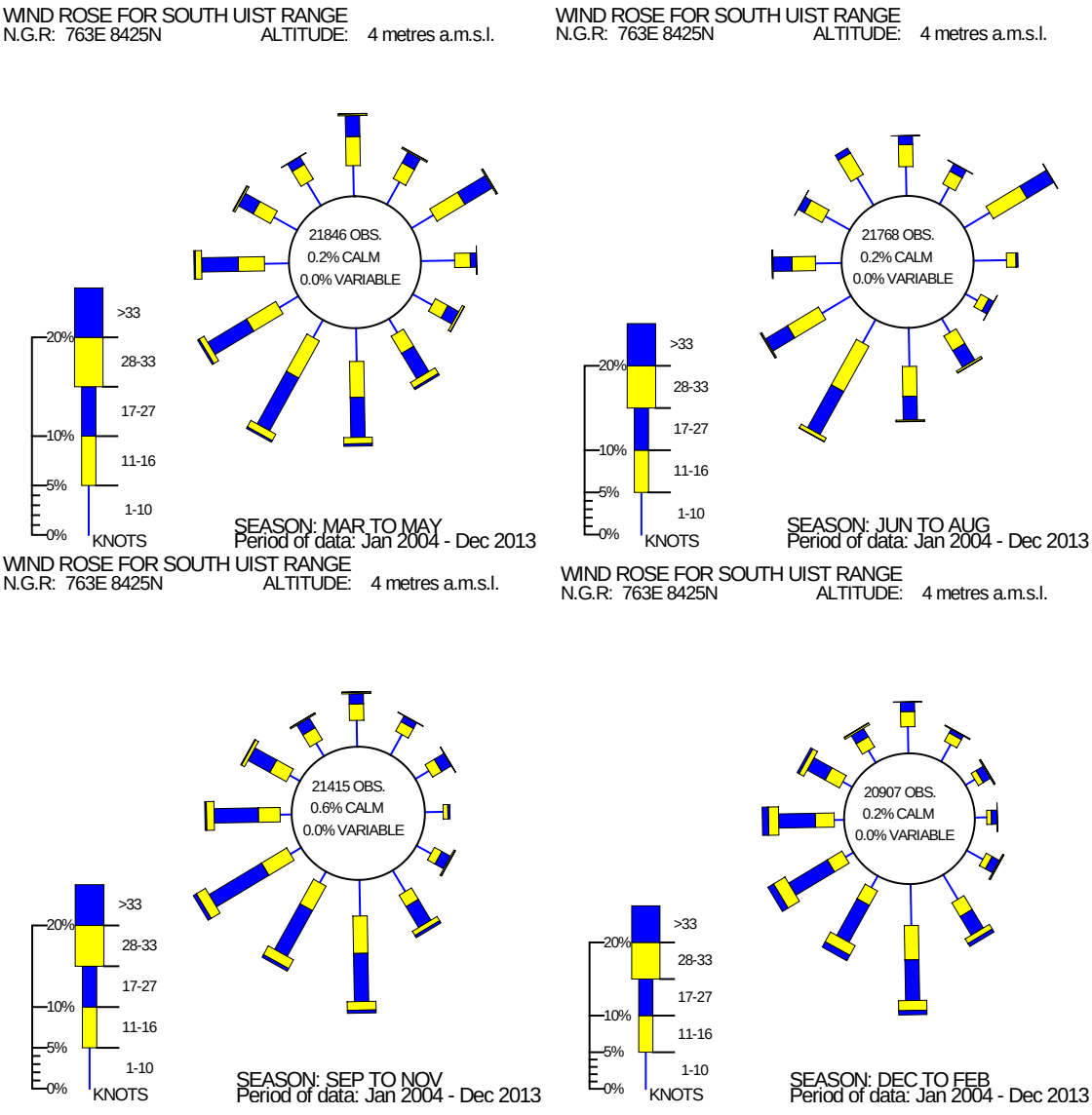


Figure reproduced under license from Meteorological Office. Crown Copyright 2012.

Figure 9.3 Seasonal wind roses for South Uist: Range

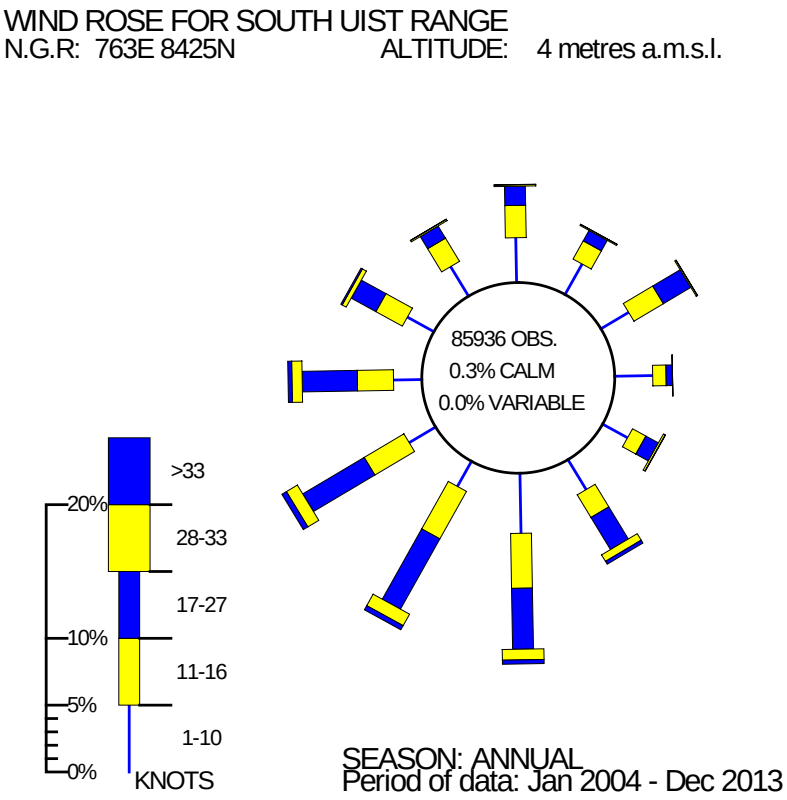


Figure reproduced under license from Meteorological Office. Crown Copyright 2012.

Figure 9.4 Annual wind rose for South Uist: Range

Overall, the strongest winds tended to come from the southwest quarter. Seasonally the strongest winds occurred during the autumn and winter with those from the south and west predominating in the spring and summer a notable proportion of strong winds come from the east-northeast.

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

10. Classification Information

Loch Eishort is classified for production of common mussels (*Mytilus edulis*). It has been classified for production since at least 2001, which were the earliest records available for review. The classification history since 2006 are given in Table 10.1 below.

Table 10.1 Loch Eishort: (common mussel) classification history

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2006	A	A	A	A	A	B	B	B	B	A	A	A
2007	A	A	A	A	A	B	B	B	B	A	A	A
2008	A	A	A	A	A	A	A	A	A	A	A	A
2009	A	A	A	A	A	A	A	A	A	A	A	A
2010	A	A	A	A	A	A	A	A	A	A	A	A
2011	A	A	A	A	A	A	A	A	A	A	A	A
2012	A	A	A	A	A	A	A	A	A	A	A	A
2013	A	A	A	A	A	A	A	A	A	A	A	A
2014	A	A	A	A	A	A	A	A	A	A	A	A
2015	A	A	A									

The production area has had a year-round A classification since 2008.

11. Historical *E. coli* Data

11.1 Validation of historical data

Results for all samples assigned against Loch Eishort production area for the period 01/01/2009 to the 12/06/2014 were extracted from the FSAS database on 12/06/2014 and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. All *E. coli* results were reported as most probable number (MPN) per 100 g of shellfish flesh and intravalvular fluid.

Forty-three sample results reported as <18 or <20 were reassigned a value of 10 *E. coli* MPN/100 g for the purposes of statistical evaluation and graphical representation.

Two sample results were noted as rejected on the database and were omitted from further analysis for this report. The remaining 65 samples were all received within 48 hours of collection, had box temperatures <8^{o}C and were taken from within the Loch Eishort production area.

11.1 Summary of microbiological results

Sampling and result summaries of results assigned to Loch Eishort between 2009 and 2014 are displayed in Table 11.1.

Table 11.1 Summary of historical sampling and results

Sampling Summary	
Production area	Loch Eishort
Site	Drumfearn
Species	Common mussels
SIN	SL-137-281-08
Location	Various
Total no of samples	65
No. 2009	13
No. 2010	12
No. 2011	12
No. 2012	12
No. 2013	12
No. 2014	4
Results Summary	
Minimum	<20
Maximum	5400
Median	<20
Geometric mean	20.5
90 percentile	170
95 percentile	1009
No. exceeding 230/100g	4 (6%)
No. exceeding 1000/100g	3 (5%)
No. exceeding 4600/100g	1 (2%)
No. exceeding 18000/100g	0

Sampling has been even across years and the majority of results were <230 *E. coli* MPN/100 g.

11.2 Overall geographical pattern of results

The geographical locations of all sample results assigned to Loch Eishort are mapped thematically in Figure 11.1. Seven of the reported grid references lacked the two letter prefix NG, so these were added prior to mapping. One sample did not have a reported sampling location and was therefore left out of the geographical analysis. All sample locations were reported to at least 10 m accuracy, with most reported to 1 m accuracy.

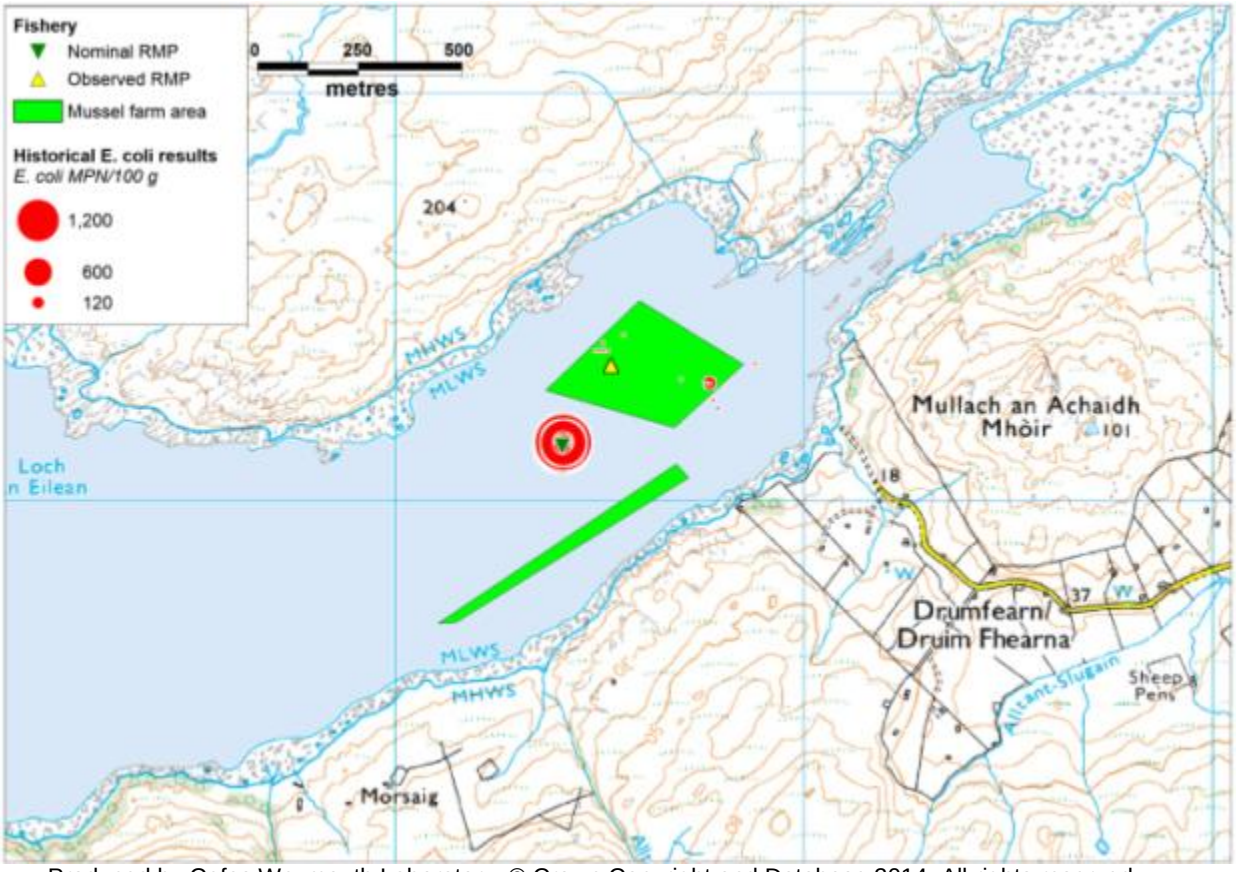


Figure 11.1 Map of reported sampling locations for common mussels at Loch Eishort

The majority of results (n=46) were reported against the nominal RMP, the most recent of which was reported in April 2014. This location lies 120 m from the nearest point on the Site 1 North (Drumfearn) mussel farm as recorded during the shoreline survey. The RMP location observed during the shoreline survey was recorded as NG 6653 1633. All results >230 *E. coli* MPN/100 g were reported against the nominal RMP. However, it is not clear where on the mussel farm these samples were actually taken. It is therefore not possible to undertake any meaningful analysis of geographic variation in historical monitoring results.

11.3 Overall temporal pattern of results

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

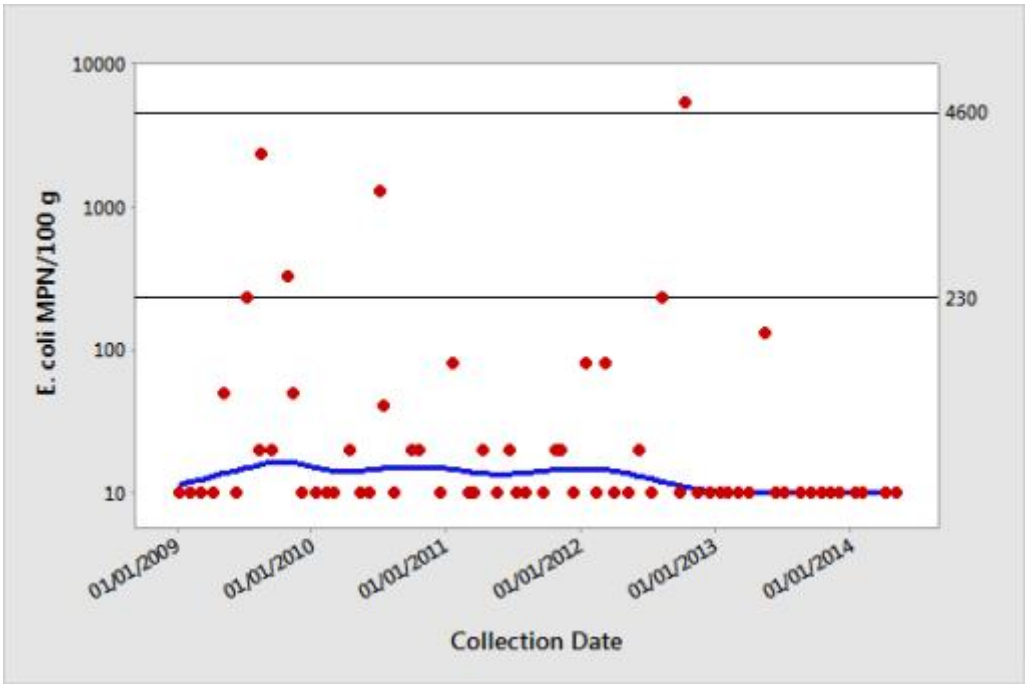


Figure 11.2 Scatterplot of *E. coli* results by collection date at Loch Eishort, fitted with a lowess line

Results remained low overall over the period considered here, with markedly more variation during the period up to late 2012. After October 2012, the large majority of results have been below the limit of detection. Prior to January 2013, nearly all samples were reported against the nominal RMP. After this date, most samples were taken from locations further to the north and/or east on the mussel farm. Satellite imagery from 2012 (BingMaps) was reviewed to assess whether there had been a change in the location of the Site 1 North (Drumfearn) mussel farm. The imagery date for the Loch Eishort area was May 2012 (http://mvexel.dev.openstreetmap.org/bing/, accessed 16/07/2014), and the locations of the North Site 1 mussel lines visible in the image coincided closely with the location recorded during the shoreline survey. It is possible, therefore, that the change in monitoring results was due to a change in monitoring location(s). However, this cannot be confirmed due to uncertainty surrounding the locations of the earlier samples.

11.4 Seasonal pattern of results

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns in human distribution. All of these can affect levels of microbial contamination, causing seasonal patterns in results. A scatterplot of *E. coli* results by month, overlaid by a lowess line to highlight trends for Loch Eishort is displayed in Figure 11.3. Jittering was applied to at 0.02 (x-axis) and 0.001 (y-axis) respectively.

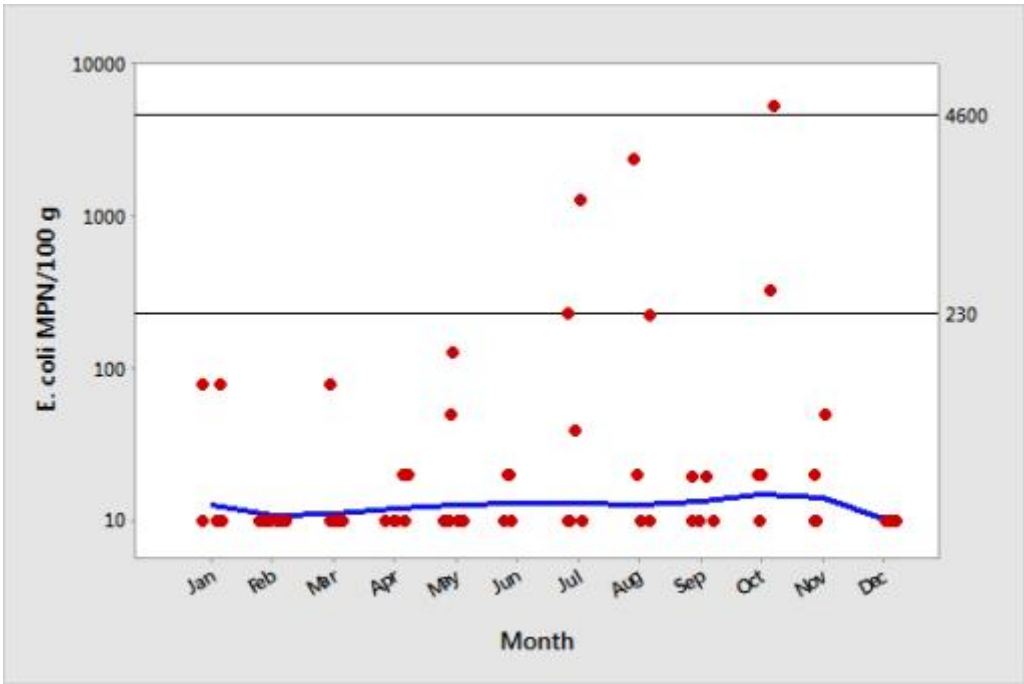


Figure 11.3 Scatterplot of *E. coli* results by month at Loch Eishort, fitted with a lowess line

Low results were reported in all months, however results ≥230 *E. coli* MPN/100 g were reported in July, August and October.

For statistical evaluation, seasons were split into spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). A boxplot of *E. coli* results by season for Loch Eishort is presented in Figure 11.4.

No significant differences were found between *E. coli* results for Loch Eishort by season (one-way ANOVA, p = 0.145) (Appendix 4).

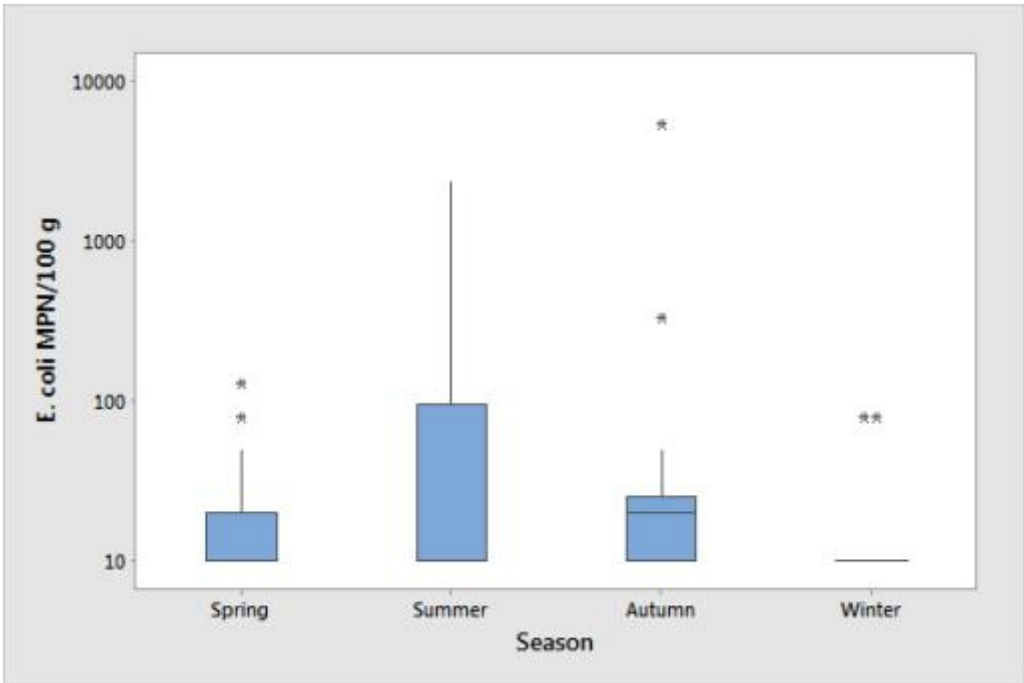


Figure 11.4 Boxplot of *E. coli* results by season at Loch Eishort

11.5 Analysis of results against environmental factors

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

11.5.1 Analysis of results by recent rainfall

The nearest weather station with available rainfall data was at Skye: Lusa approximately 10 km north of Loch Eishort. Rainfall data was purchased from the Meteorological Office for the period of 30/12/08 - 31/12/2013 (total daily rainfall in mm).

Two-day rainfall

A scatterplot of *E. coli* results against total rainfall recorded on the two days prior to sampling for Loch Eishort is displayed in Figure 11.5. Rainfall data was available for 57 of the 65 sampling occasions. Jittering was applied to results at 0.02 (x-axis) and 0.001 (y-axis) respectively.

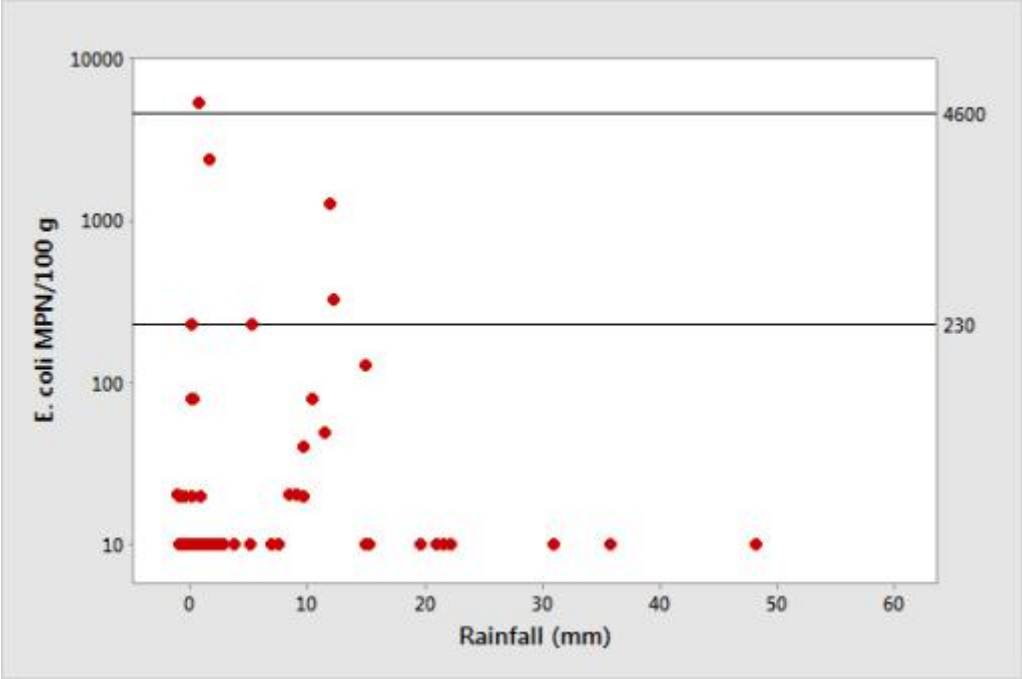


Figure 11.5 Scatterplot of *E. coli* results against rainfall in the previous two days at Loch Eishort

No significant correlation was found between *E. coli* results and rainfall during the two days prior to sampling (Spearman's rank correlation r = -0.027, p = 0.843). Highest results coincided with low rainfall values, whilst the highest recorded rainfall coincided with results below the limit of detection.

Seven-day rainfall

The effects of heavy rainfall may take differing amounts of time to be reflected in shellfish sample results in different systems. Therefore, the relationship between rainfall during the seven days prior to sampling and sample results was investigated in an identical manner to the above. A scatterplot of *E. coli* results against total rainfall recorded for the seven days prior to sampling at Loch Eishort is shown in Figure 11.6. Rainfall data was available for 54 of the 65 sampling occasions. Jittering was applied to results at 0.02 (x-axis) and 0.001 (y-axis) respectively.

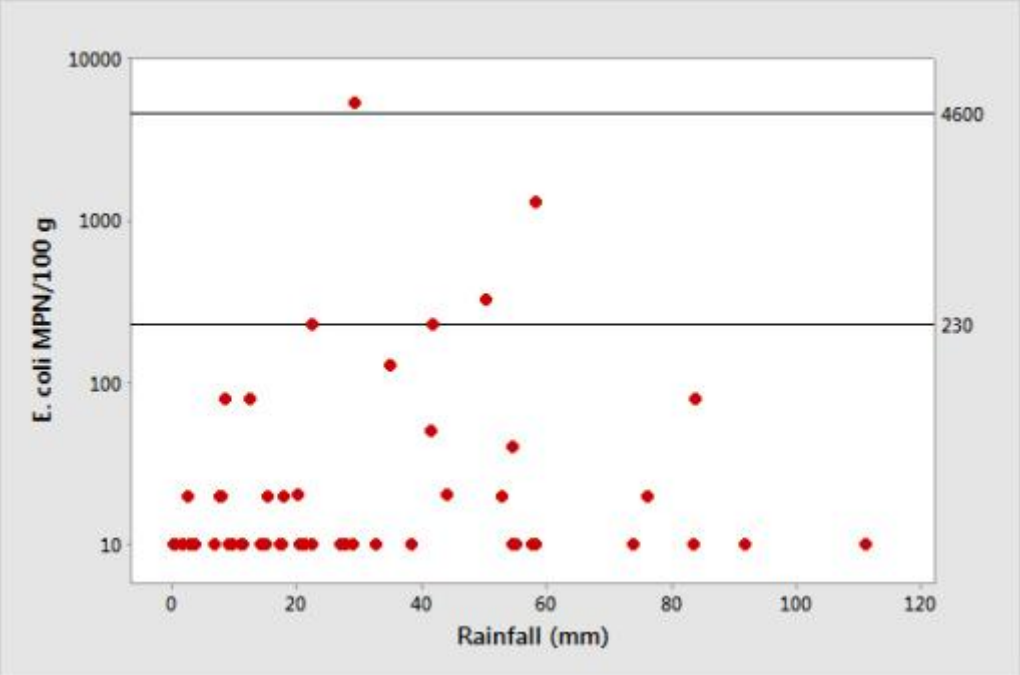


Figure 11.6 Scatterplot of *E. coli* results against rainfall in the previous seven days at Loch Eishort

No statistically significant correlation was found between *E. coli* results and the previous seven day rainfall (Spearman's rank correlation r = 0.164, p = 0.241). Results >230 E. coli MPN/100 g coincided with moderate rainfall totals.

11.5.2 Analysis of results by tidal cycle

Spring/neap tidal cycle

Spring tides are large tides that occur fortnightly and are influenced by the state of the lunar cycle. They reach above the mean high water mark and therefore increase circulation and particle transport distances from potential contamination sources on the shoreline. The largest (spring) tides occur approximately two days after the full/new moon, at about 45^{o} on a polar plot. The tides then decrease to the smallest (neap) tides, at about 225^{o}, before increasing back to spring tides. A polar plot of *E. coli* results against the lunar cycle is shown for Loch Eishort in Figure 11.7. It should be noted local meteorological conditions (e.g. wind strength and direction) can also influence tide height, but are not taken into account in this section.

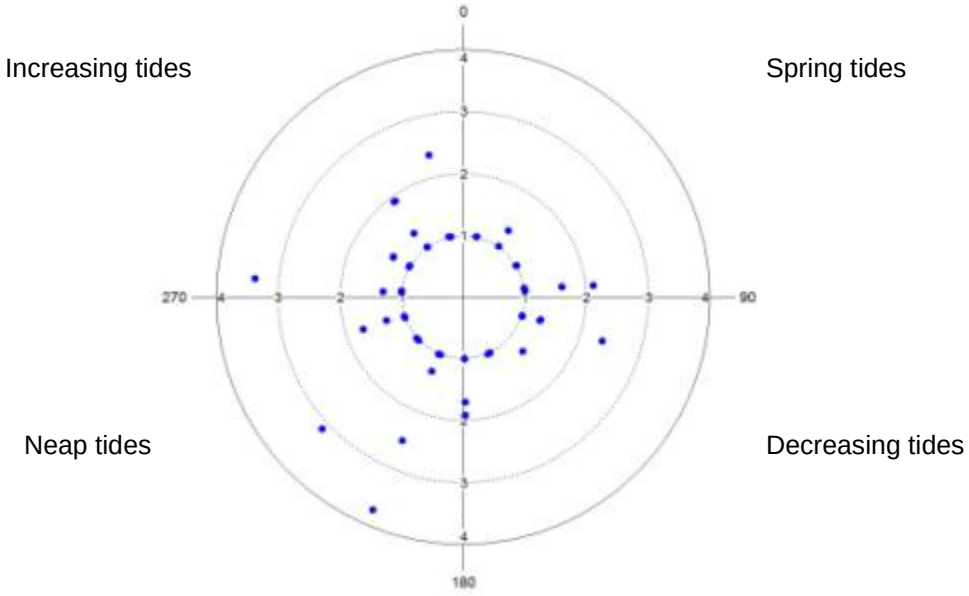


Figure 11.7 **Polar plot of log_{10} *E. coli* results on the spring/neap tidal cycle at Loch Eishort**

No statistically significant correlation was found between log_{10} *E. coli* results and the spring/neap tidal cycle (circular-linear correlation r = 0.135, p = 0. 323), despite three of the four highest results being taken at or just prior to neap tides.

High/low tidal cycle

Tidal state (high/low tide) changes the direction and strength of water flow around production areas. Depending on the location of contamination sources, tidal state may cause marked changes in water quality near the vicinity of the farms. Shellfish species response time to *E. coli* levels can vary from within an hour to a few hours. A polar plot of *E. coli* results against the high/low tidal cycle for Loch Eishort is shown in Figure 10.8. High water is located at 0^o on the polar plot and low water at 180^o.

High and low water data from Camus nan Gall was extracted from POLTIPS-3 in June 2014. This site was the closest to the production area (approximately 13 km to the west) and it is assumed that the tidal state will be similar between sites.

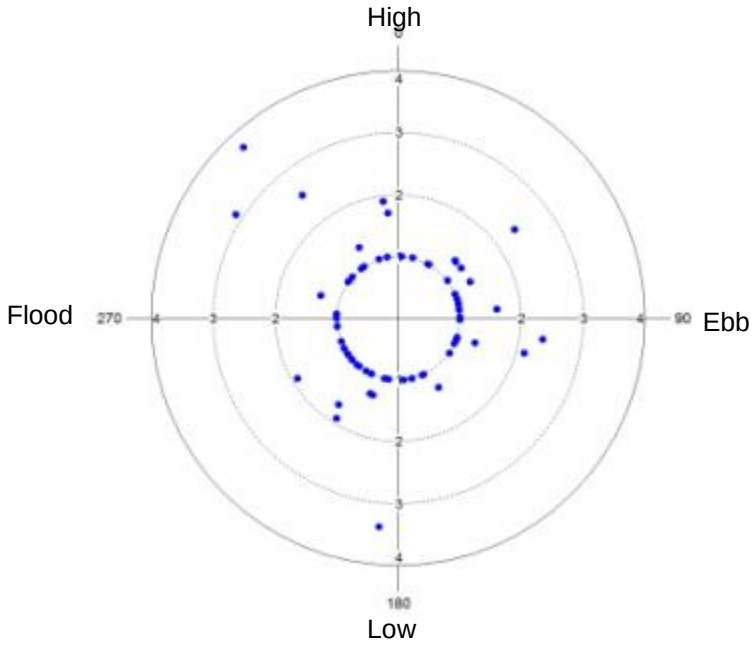


Figure 11.8 Polar plot of log_{10} *E. coli* results on the high/low tidal cycle at Loch Eishort

No statistically significant correlation was found between log_{10} *E. coli* results and the high/low tidal cycle (circular-linear correlation r = 0.133, p = 0.336). Three of the four highest results were from samples taken on the flood tide.

11.5.3 Analysis of results by water temperature

Water temperature can affect survival time of bacteria in seawater (Burkhardt, *et al*., 2000). It can also affect the feeding and elimination rates in shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. Water temperature is obviously closely related to season. Any correlation between temperatures and *E. coli* levels in shellfish flesh may therefore not be directly attributable to temperature, but to the other factors e.g. seasonal differences in livestock grazing patterns. Water temperature was recorded for 51 of the 65 Loch Eishort samples. A scatterplot of *E. coli* results against water temperature for Loch Eishort is shown in Figure 10.9.. Jittering of results was applied at 0.02 (x-axis) and 0.001 (y-axis) respectively.

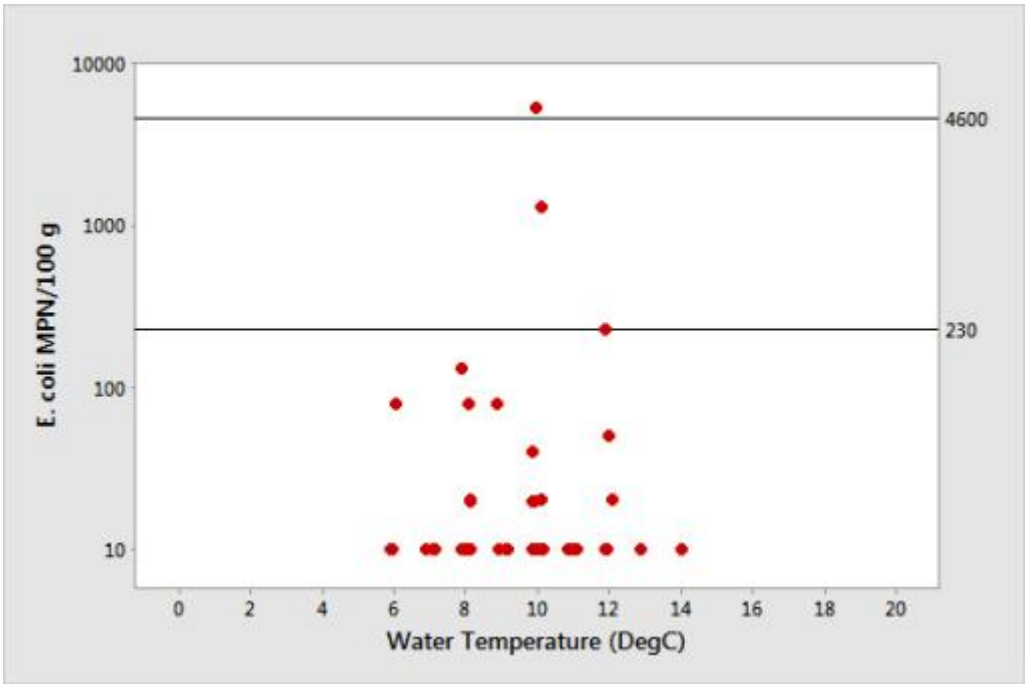


Figure 11.9 Scatterplot of *E. coli* results against water temperature at Loch Eishort

No statistically significant correlation was found between *E. coli* results and water temperature (Spearman's rank correlation r = 0.006, p = 0.964).

11.5.4 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence and hence freshwater borne contamination at a site. Salinity was recorded for only 14 (22%) of the samples, therefore no analysis of results by reported salinity was undertaken.

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

In the results from Loch Eishort four common mussel samples had results >230 *E. coli* MPN/100 g and are listed below in Table 11.2.

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

Collection Date	*E. coli* (MPN/ 100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (°C)	Salinity (ppt)	Tidal state (spring/ neap)	Tidal State (high/low)
17/08/2009	2400	NG 6641 1615	2.3	-	-	-	Increasing	Low
26/10/2009	330	NG 6641 1615	11.7	49.0	-	30	Neap	Flood
05/07/2010	1300	NG 6641 1615	10.9	58.5	10	-	Neap	Flood
08/10/2012	5400	NG 6641 1614	0.0	26.9	10	-	Neap	Flood

-No data available

Elevated results occurred during July, August and October. The highest result occurred in October 2012. All elevated results came from samples reported against the nominal RMP.

Elevated results occurred over a range of environmental conditions, though most occurred on a flooding tide during the neap portion of the tidal cycle.

11.7 Summary and conclusions

Results at Loch Eishort have been historically low, however with occasional very high results, particularly prior to 2013. A change in the reported sampling locations from January 2013 onward coincided with a step change in monitoring results, with nearly all samples taken since then returning results below the limit of detection.

Because the nominal RMP lies over 100 m from the nearest point on the Site 1 North mussel farm, it is not possible to ascertain where samples attributed to that point were taken. As this applied to the large majority of samples (71%), it was not possible to assess geographic variation in results.

The highest *E. coli* monitoring results from Loch Eishort occurred in July, August and October, though analysis by season showed no statistically significant seasonal effect .

No statistically significant differences were found between results and previous two or seven day rainfall, or between results and water temperature. It was not possible to assess results by salinity as this parameter was not recorded on enough occasions to provide sufficient data.

No statistically significant correlation was found between results and the spring/neap or high/low tidal cycles although there was a tendency for high results to be seen in samples taken on a flooding neap tide.

12. Designated Waters Data

Shellfish Water Protected Areas

The Shellfish Waters Directive (2006/113/EC) has been repealed (as at 31 December 2013) and equivalent protection for areas previously designated under that Directive is given by The Water Environment (Shellfish Water Protected Areas: Environmental Objectives etc.) (Scotland) Regulations 2013. The Loch Eishort Shellfish Water Protected Area (SWPA) has the same boundaries as the previous Loch Eishort Shellfish Growing Water (SGW). The SWPA designation covers the eastern end of Loch Eishort and has the same boundary as the Loch Eishort production area and includes the Loch Eishort fisheries. There is an historic SGW monitoring point located in Loch Eishort at NG 6706 1629. Since 2007, SEPA has used the FSAS *E. coli* data for assessing microbiological quality. The designated SWPA for Loch Eishort is shown in Figure 12.1.

The SGW report for Loch Eishort (SEPA, 2011) identified that there would be diffuse pollution from livestock associated with crofts at Heast and Drumfearn as well as sewage discharges from clusters of houses in these two areas.

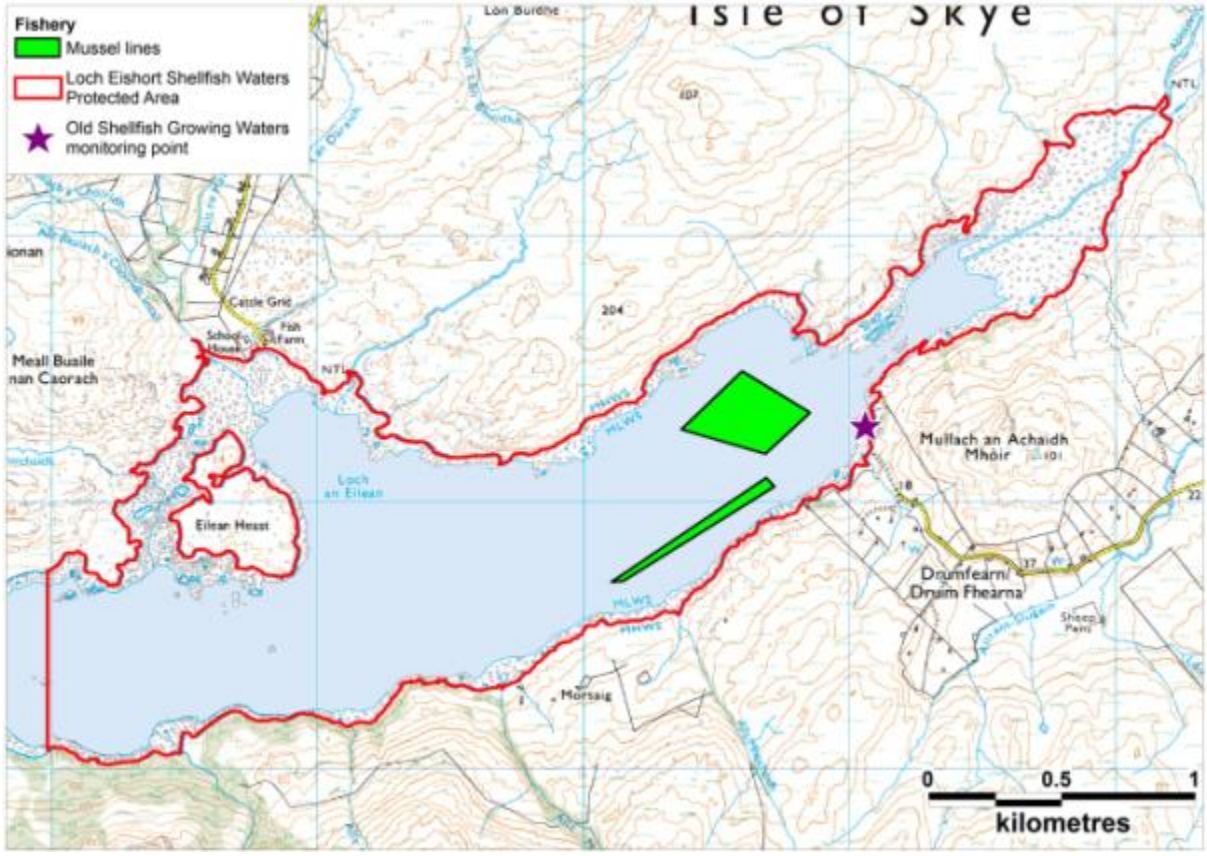


Figure 12.1 Designated shellfish water protected area – Loch Eishort

Bathing Waters

There are no designated bathing waters within Loch Eishort.

13. Bathymetry and Hydrodynamics

13.1 The Study Area

Loch Eishort is situated on the south west coast of the Isle of Skye in the Highland district of the west coast of Scotland. The surrounding area is characterised by low hills, and lies in a sparsely populated region away from industrial activities and agriculture. At its mouth, Loch Eishort joins with neighbouring Loch Slapin at Rubha Suisnish. Numerous streams and small rivers flow into the loch, including Allt na Pairte, Allt na Heast, and Allt Lon Bhuide along the northern edge of the loch; the Ord River and Allt a' Chinn Mhòir along the southern edge of the loch; and Lòn Creadha and Abhainn Ceann at the head of the loch. Three small settlements border Loch Eishort: Heaste, Drumfearn, and Ord.

The assessment area encompasses Loch Eishort, to the east of Rubha Suisnish (northern boundary) and to the east of the western point of the bay Òb Ghabhsgabhaig (southern boundary). It is shown in Figure 13.1 with the assessment area demarcated by the red line. The total length of Loch Eishort is 10 km. The western portion of Loch Eishort is approximately 3 km in width, while the eastern portion narrows to approximately 600 m in width.

Coordinates for Loch Eishort:

57.163459°N 005.954448°W

OS GB36 161000 815005

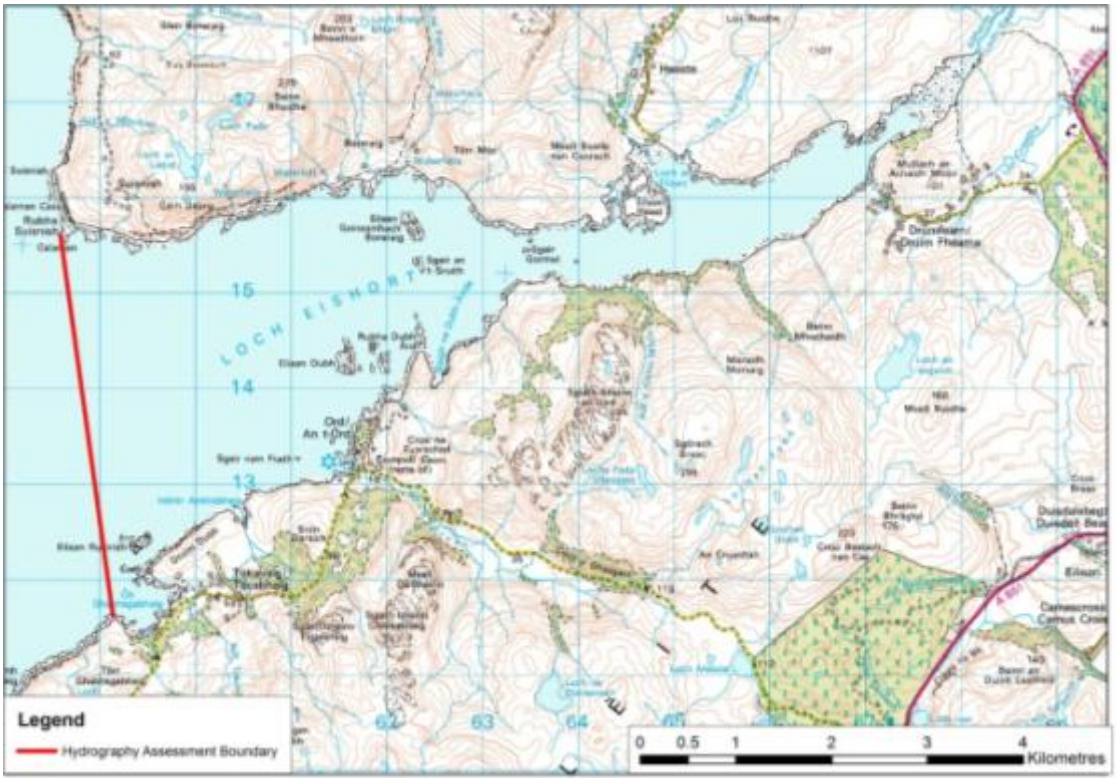


Figure 13.1 Extent of the hydrographic study area

13.2 Bathymetry and Hydrodynamics

13.2.1 Bathymetry

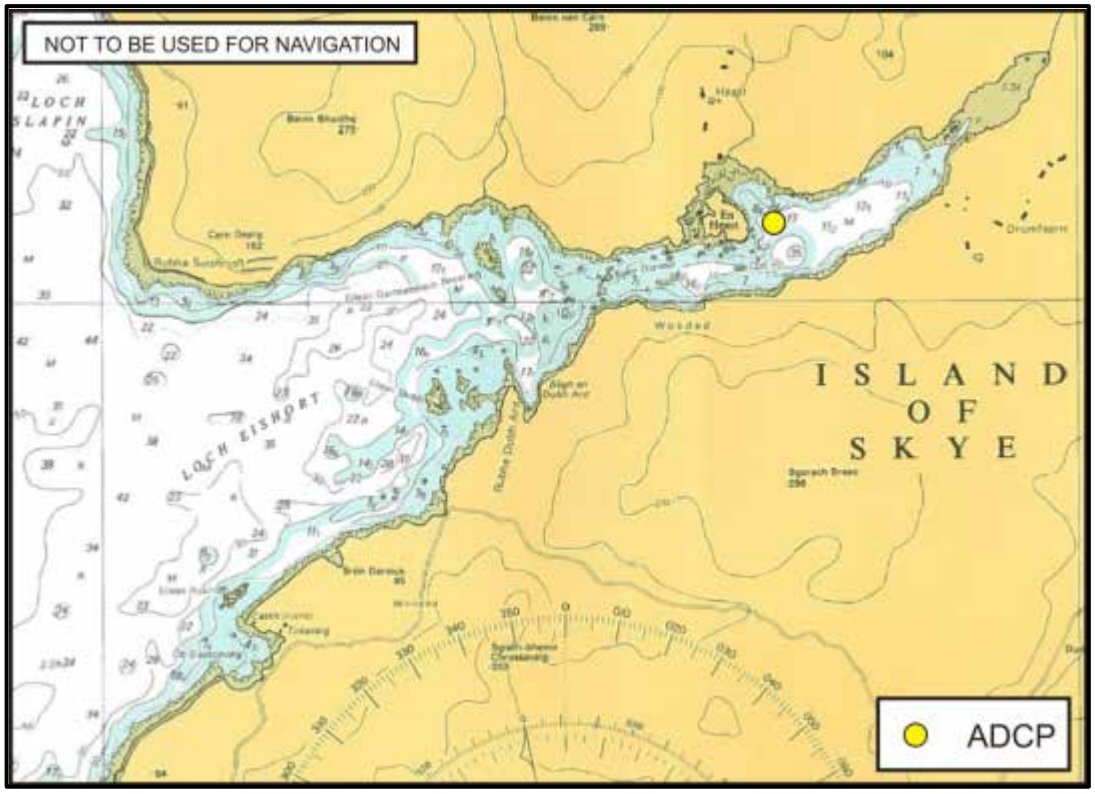


Figure 13.2 Admiralty chart (2208, Edition 12 year 1992) extract for Loch Eishort. ADCP station within assessment area is shown.

Figure 13.2 shows the bathymetry of Loch Eishort. Two sills are found in the loch. The first incorporates a series of tidally exposed rocks including Sgeir Gormul, and is on average 2 m in depth with a maximum depth of 8 m, while the second extends from the island En Heast, and is on average 3 m in depth with a maximum depth of 7 m (Edwards & Sharples, 1986). To the west of the first sill bathymetry slopes gently from 10 m to 38 m at the western boundary of the assessment area, while a maximum charted depth of 35 m can be found in an isolated deep area to the east of the latter sill. Between the two sills, depths range from 5 to 16 m in a relatively small basin.

The mean depth of the assessment area at low water is 9.2 m, while the estimated low water volume is 2.1×10^7 m^3 (Edwards & Sharples, 1986).

There is a fairly extensive intertidal area at the head of Loch Eishort of approximately 0.5 km^2.

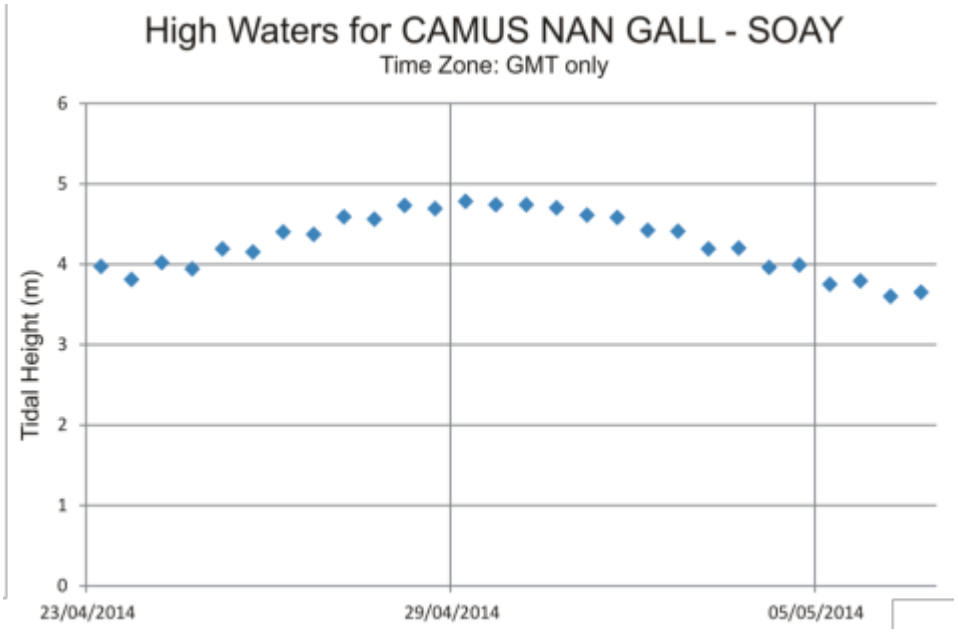
13.2.2 Tides

Data on tidal information is provided based on tidal characteristics from adjacent sites, or information from publications. Tidal constituent data for Loch Eishort does not exist and the nearest locations with data to permit tidal predictions are Camus

Nan Gall, Isle of Soay, located approximately 13 km west of the survey area boundary [http://easytide.ukho.gov.uk], and Bay of Laig, Isle of Eigg, approximately 23 km to the south of Loch Eishort [www.pol.ac.uk/appl/poltips3].

Standard tidal data for Camus Nan Gall, centred around the survey date of 30th April 2014, is shown in Figure 13.3. The full tidal curve data for Bay of Laig, Isle of Eigg is shown in Figure 13.4 for the same period.

Although data for Loch Eishort does not exist, the tidal predictions presented for Camus Nan Gall and Bay of Laig (which span the geographic area) show that in this region the tidal characteristics are clearly semi-diurnal with a well-developed spring-neap cycle. Similarity between the tidal characteristics shown in these two curves indicates that tides in Loch Eishort would closely approximate this pattern also. The timing of high and low tides in the inner part of Loch Eishort will be slightly later than indicated in the figures due to the tidal lag created by the shallow sill in the Loch.



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

Figure 13.3 **Two week tidal curve (high water predictions only) for Camus Nan Gall, Soay**

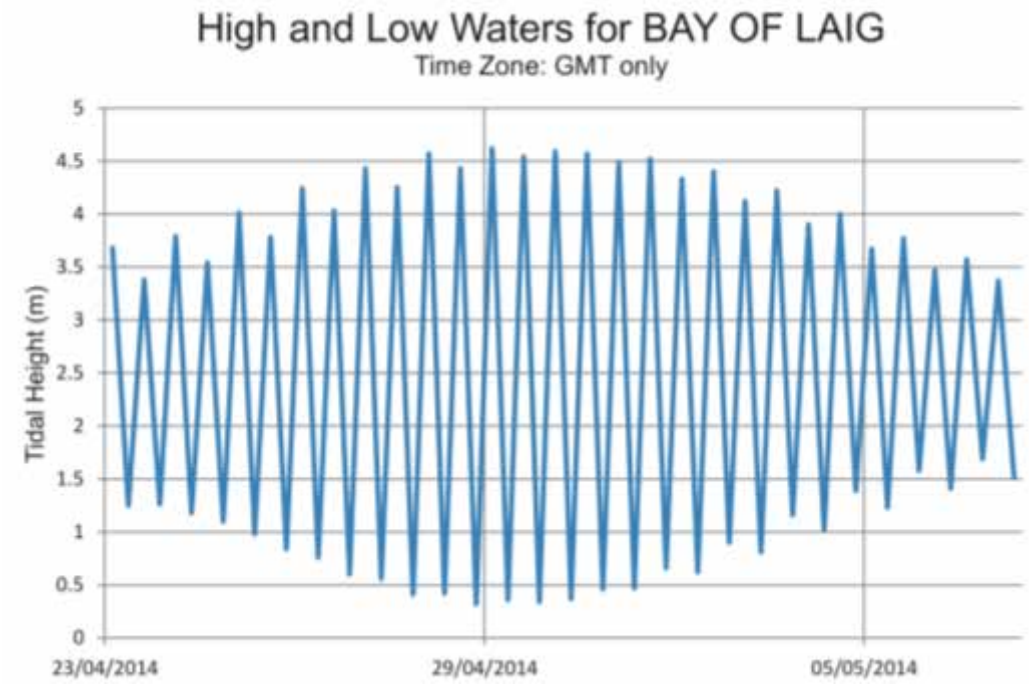


Figure 13.4 Two week tidal curve for Bay of Laig, Inner Hebrides.
Reproduced from Poltips3 [www.pol.ac.uk/appl/poltips3]

Tidal Heights in Loch Eishort, data are from Laurence (1990):

Mean High Water Springs = 4.80 m
Mean Low Water Springs = 0.70 m
Mean High Water Neaps = 3.70 m
Mean Low Water Neaps = 2.10 m

There is also a reported tidal range for Loch Eishort of 4.3 m (Marine Scotland, 2012). This gives an approximate tidal volume of water within the assessment area during each tidal cycle of:

Springs: 5.9×10^7 m^3
Neaps: 2.7×10^7 m^3

13.2.3 Tidal Streams and Currents

There are no published tidal diamonds for this area. Enhancement of tidal streams caused by straights and shallow areas will be important around shallow and tidally exposed rocks along each sill in Loch Eishort.

Current meter data was available at one specified site within the assessment area. Data were obtained from SEPA for a site approximately 300 m to the east of Eilean Heast at Loch an Eilean, shown in figure 13.5. This survey spanned 15 days (University of Stirling, 2001); a half-lunar period, necessary to capture a spring-neap cycle.

Current meter data were also obtained from SEPA at one further site in Loch Eishort in 1998, though no location information was available. These data were collected over 12 days.

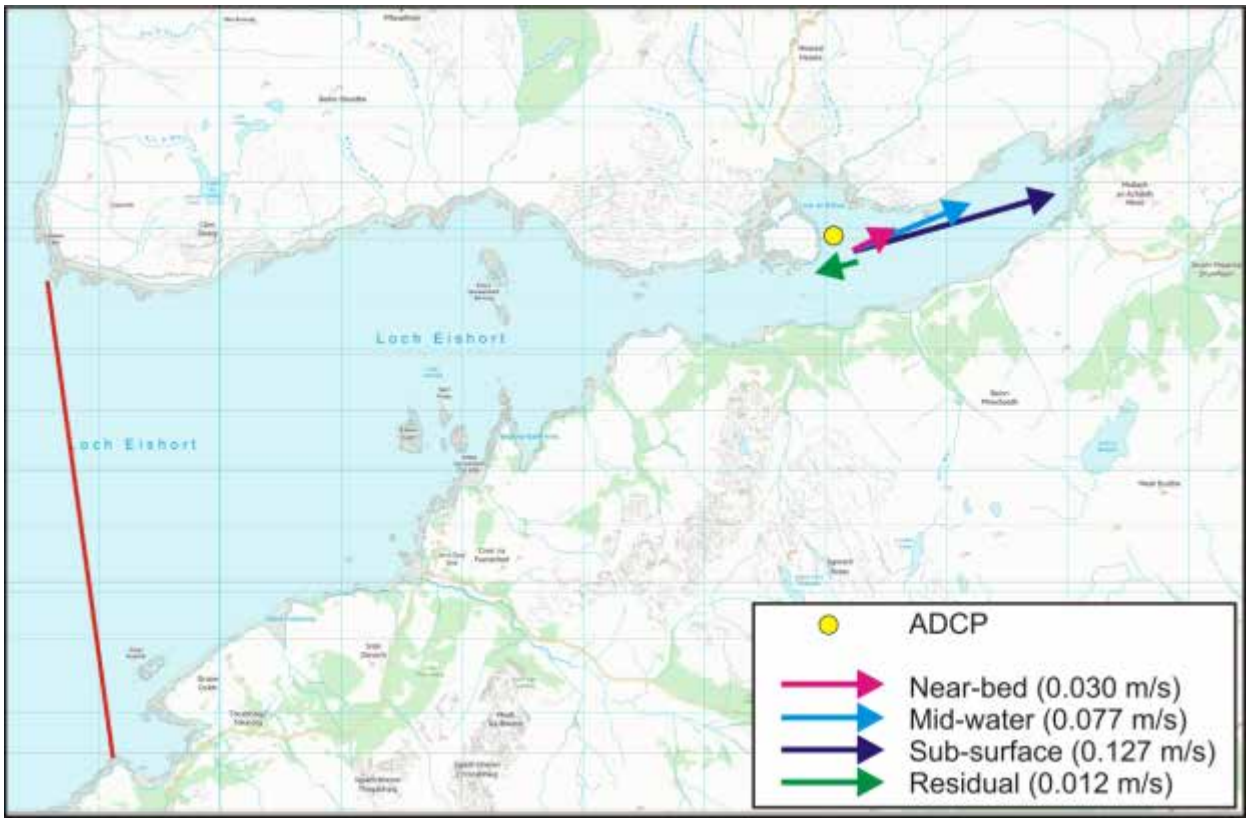


Figure 13.5 Map showing 2001 Loch Eishort sample site within the assessment area. Using the principal current amplitude at each measured depth and the assumption of a uniform sinusoidal tide, the cumulative transport distance and direction is shown above.

Data from Loch an Eilean, Loch Eishort, NG 65220 E, 15845 N were collected between 14/02/2001 and 01/03/2001 and are summarised in Table 13.1.

Table 13.1 Loch an Eilean current data measured in 2001

Average Depth	Near-bed (11.7 m below surface)	Mid-water (6.4 m below surface)	Sub-surface (2.8 m below surface)
Mean Speed (ms^{-1})	0.008	0.019	0.040
Maximum Speed (ms^{-1})	0.090	0.125	0.160
Principal Axis Amp & Dir (ms^{-1}) & (^oM)	0.03 (063)	0.077 (068)	0.127 (074)
Residual speed (ms^{-1})	0.002	0.006	0.012
Residual direction (^oM)	011	306	255

The accompanying report states that surface and mid-water currents at this site were most frequently characterised by flows to the WSW, though strongest currents were observed in a north-easterly direction. Surface currents did not show a distinct pattern over the spring-neap cycle. Seabed currents were much slower and the direction of flow was variable, but frequently oriented north-south.

A wind station was also deployed during the Loch an Eilean survey. Hourly wind speeds rarely exceeded 10 m/s and varied between east and north-west in direction.

The maximum recorded wind speed was 20.5 m/s. Some similarities were observed between periods of strongest current flow at all depths and high wind speeds, so it likely there is a coupling between currents and wind forcing at this location.

Current data were also collected in Loch Eishort over 12 days between 10/01/1998 and 22/01/1998, though no location coordinates were available for this current meter deployment (University of Stirling, 1998). These data are summarised in Table 13.2.

Table 13.2 Loch Eishort current data measured in 1998
No location coordinates were available for these measurements

Approximate Height/Depth	Near-bed (3 m above seabed)	Sub-surface (3 m below surface)
Mean Speed (ms^{-1})	0.032	0.085
Maximum Speed (ms^{-1})	0.21	0.35
Principal Axis Amp & Dir (ms^{-1}) & (^{o}M)	0.094 (136)	0.250 (031)
Residual speed (ms^{-1})	0.006	0.022
Residual direction (^{o}M)	022	231

Residual currents at the surface were oriented towards the south-west, while towards the seabed there was little directional flow. Currents at both depths dropped to 0 ms^{-1} at times of slack water. During current meter deployment, the majority of recorded wind speeds were less than 10 ms^{-1}, such that there was probably minimal wind effect on current speeds.

In general, the data from Loch an Eilean indicates relatively weak flows and this supports the SEPA summary data where the site is classified as quiescent.

Using a typical surface principal current and assuming a uniform sinusoidal tide, the cumulative transport that might be expected during each phase of the tide (approximately 6 hours) has been estimated for the 2001 Loch an Eilean site as 1.7 km (based on a surface principal current amplitude of 0.13 ms^{-1}). No distinction is made here for springs and neaps.

Dispersion is an important property of a water body with respect to redistribution of contaminants over time. There are no measurements or published data relating to dispersion in Loch Eishort. Without such data, it is difficult to judge what the dispersive environment might be like. However, dispersion is likely to be enhanced by flow around the small islands and tidally exposed rocks in the western portion of Loch Eishort, as well as across the two shallow sills in the middle portion of the loch.

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

13.2.4 River/Freshwater Inflow

One main river, Abhainn Ceann, flows into Loch Eishort at its northeastern end, while numerous other small rivers flow into the study area from the surrounding hillsides. These include Allt na Pairte, Allt na Heast, and Allt Lòn Bhuidhe to the north of the loch, and the Ord River and Alt a' Chinn Mhòir to the south, as well as a number of smaller burns.

The annual precipitation in the area is approximately 1850 mm and the annual freshwater runoff is estimated as 117.9 M m^3 yr^{-1} (Edwards & Sharples, 1986). The ratio of fresh water flow to tidal flow is moderate at approximately 1:(Edwards & Sharples, 1986), though this ratio will be seasonally variable.

13.2.5 Meteorology

The nearest weather station for which a near complete rainfall dataset is available is located at Lusa, Skye. This station is situated approximately 10 km to the north of the assessment area. Rainfall records are available from January 2008 to December 2013. Analysis of this data is presented in Section 9. Run-off due to rainfall is expected to be highest in the autumn and winter months. However, it must also be noted that high rainfall events occurred in most months and consequently that high run-off can occur throughout the year.

Wind data were collected from South Uist at a site over 80 km to the west of the assessment area. Given the substantial distance between these two locations, wind statistics may not be directly transferrable to the specific production area in Loch Eishort. Wind roses for this station are presented in Section 9. Wind direction in Loch Eishort is likely to be influenced by the surrounding topography, which is particularly mountainous to the north and east of the assessment area.

13.2.6 Model Assessment

The exchange characteristics of Loch Eishort were assessed using a layered box model approach. The model represents the Loch as a box made up of three layers and was formulated according to the method of Gillibrand *et al* (2013). The box layers are forced with surface wind stress, estimates of fresh water discharge, surface heat flux parameters and, at the open coastal boundary, profiles of temperature and salinity are prescribed from climatology compiled by the UK Hydrographic Office. This sets the model with climatological boundary conditions to represent an 'average' year. The model has been tuned and validated for Lochs Creran and Etive. A full validation for Loch Eishort has not been done.

The box model quantifies the primary exchange mechanisms. The key outputs from the model with respect to this hydrographic assessment is a series of annual mean values that describe the relative importance of the estuarine (gravity) exchange, tidal exchange, and the flushing time, which is the inverse of the exchange rate. These values are given in Table 13.3.

Table 13.3 Summary of annual mean parameter values from the box modelling exercise

Parameter	Value
Tidal Volume Flux ($m^3 s^{-1}$)	188.8
Estuarine Circulation Volume Flux ($m^3 s^{-1}$)	47.6
Median Flushing Time (days)	0.9
95%-ile Flushing Time (days)	1.4

The ratio of tidal volume flux to estuarine circulation volume flux is 4.0. Values greater than 2 indicate a system that is strongly tidal in its exchange characteristics (Gillibrand, *et al*., 2013).

The exchange time for the surface and intermediate layers is calculated as 0.9 days compared to the tidal prism estimate of 1.4 days (Marine Scotland, 2012). The relatively close agreement confirms that this assessment area is effectively flushed.

13.3 Hydrographic Assessment

13.3.1 Surface Flow

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

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

From the current meter record on the north side of the assessment areas the tidal flow appears to be broadly aligned with the shore. It is anticipated that the tidal flow would be similar on the east side, flowing into the loch on the flood and out of the loch on the ebb. The cumulative transport distance on each phase (flood/ebb) of the tide has been estimated at around 1.7 km within the assessment area.

Residual flows are relatively weak, indicating that the estuarine circulation is rather weak in this area. However, surface residual flows would be enhanced by winds blowing out of the loch, from the east. Winds will also further enhance the mixing of

the waters through the full depth. The topography of the land is likely to steer the wind along the axis of the loch enhancing the in/out flow of surface waters.

Net transport of contaminants is related to the residual flow documented in Tables 13.1 and 13.2. The residual flow measured in the surface waters of the assessment area was variable and likely related to variation in the local wind and freshwater conditions. Using the residual flow speeds at the surface measured in 2001 (0.012 m/s), the net transport over a tidal cycle of approximately 12 hours would be around 0.5 km.

From the rather limited current meter measurements in Eishort it is likely that any surface contaminant in the inner part of the loch would be transported primarily along the shoreline. In the region of the sills, it is expected that there will be enhanced dispersion into the outer part of the loch towards the Minch except in periods of strong onshore winds.

13.3.2 Exchange Properties

The box modelling has shown that the flushing time for the surface and intermediate depth waters within the assessment area is around 1 day. Whilst this is already a rather fast flushing time, it might be further modified by wind effects which will enhance or retard the surface flows, though down-loch winds from the east are shown to be relatively rare. Similarly, exchange rates may be reduced during strong up-loch winds from the west, which are considerably more prevalent. Therefore, the flushing characteristics for the surface waters of the assessment area can be described as being ‘well flushed’, with the potential for reduced flushing efficiency due to prevailing winds.

There is a limited amount of available current meter data for Loch Eishort and there is a paucity of measured hydrographic data. There is no descriptive literature on exchange properties for the area and the topography is quite complex in the inner part of the assessment area. However, it was possible to make a broad assessment of the likely exchange rates and the impact of wind. Consequently, the confidence level of this assessment is LOW.

14. Shoreline Survey Overview

The shoreline survey at Loch Eishort was conducted on the 28th April 2014, with re-sampling of freshwater samples conducted on the 17th June 2014. No rainfall was recorded in the 48 hrs prior to either day and no rainfall was recorded during either survey. During the initial survey the weather was mostly sunny with temperature between 14 and 16 °C, wind speed of F1-2 in a northerly direction and sea state of slight. On the additional sampling day, the temperature was 20°C, with a very light NW breeze and a calm sea state.

The fishery was comprised of two common mussel sites. The larger site (identified as Site 1 North by the harvester, Peter MacAskill) is located at the head of the loch and is comprised of 17 long-lines, with 7 m droppers Mr MacAskill hoped to extend the farm in the future. The second site (Morsaig) is owned by Robert Kelly and consisted of 6 long-lines with 7 m droppers. There were no mature mussels on the lines at the time of the survey. Harvesting was noted to take place at both sites year round, though Mr MacAskill stated spat settlement had been poor over the last 12-18 months.

The shoreline adjacent to the shellfish farms is largely uninhabited. Small pockets of human population were noted at Heaste (1.5 km northwest of the Morsaig site) where 25 private dwellings were observed and at Drumfearn (300 m south of Site 1) where four houses including a croft were noted. No septic tanks or pipes were observed. No hotels, B&Bs or caravan sites were observed around the loch. A floating jetty, six fishing boats and a yacht were noted at Heaste.

Sheep were the most common livestock observed. Eight sheep were observed by a small farm/croft near Drumfearn (south), another eight were observed on the grassy shoreline at Heaste (north) and a further 15 on the island of Eilean Heaste. Cattle (n=14) were also observed grazing on the grassy shoreline close to Heaste.

The shoreline was rocky, with a gradual incline from the shore to wild grassland on the foreshore with a few birch trees. Small areas for livestock grazing were also noted.

Six watercourses were sampled; Allt Mhochaldh and one unnamed on the south shore; Allt Lon Bhuidhe, Allt an Daraich, Allt Bealach a' Choiridh Losall and Allt Murchaidh on the north shore. The highest freshwater sample (200 *E. coli* cfu/100 ml) was taken at Allt Bealach a'Choiridh Losall, with livestock noted in the vicinity of this watercourse. Other high *E. coli* results were noted in watercourses to the southeast and northwest of the mussel farms.

Seabirds were the most common wildlife observed, though present in small numbers. A decomposing whale (approximately 3-4 m long) was also observed on the shore close to Heaste.

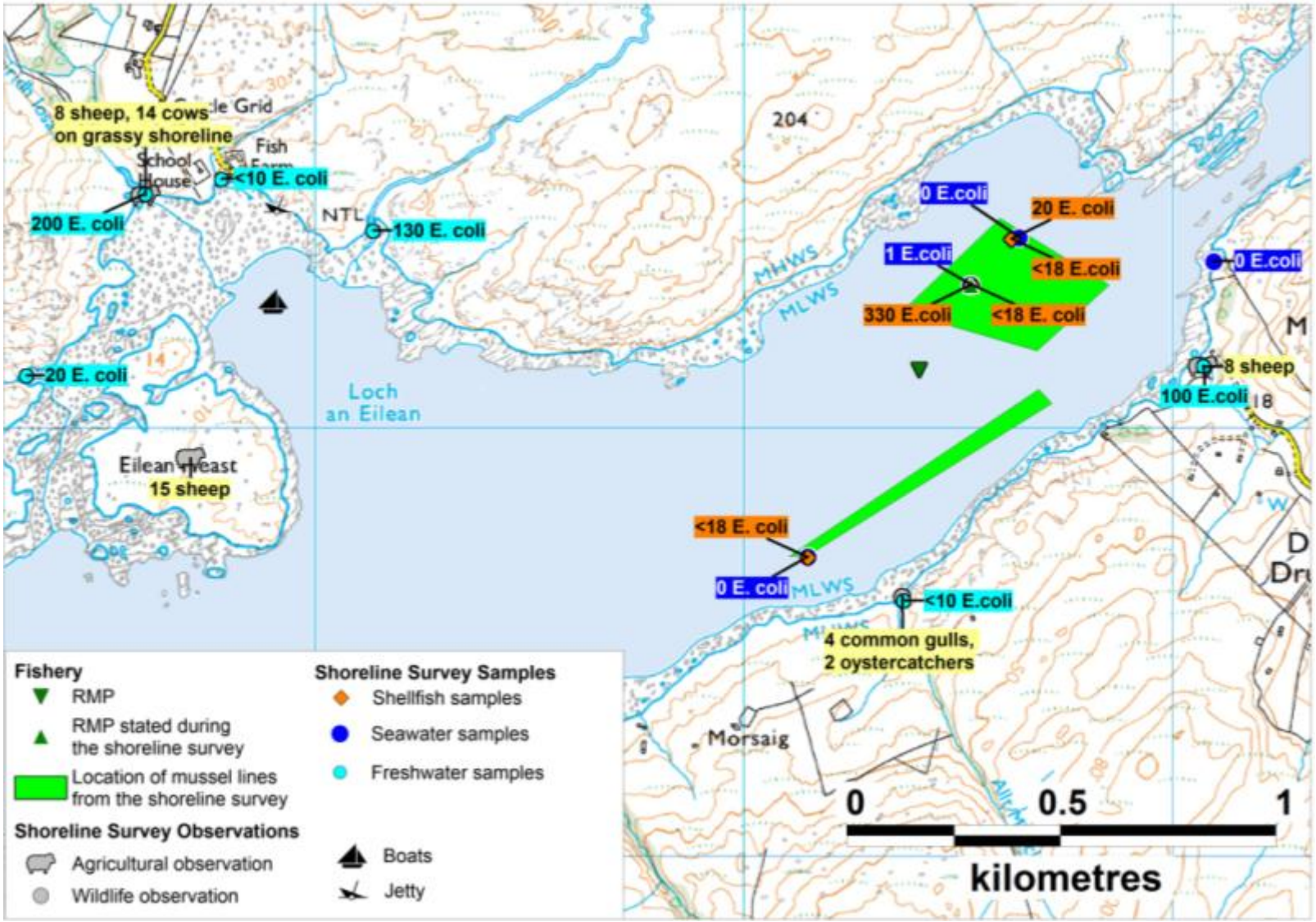


Figure 14.1 Map of shoreline survey observations at Loch Eishort

15. Bacteriological Survey

No bacteriological survey was undertaken as part of this sanitary survey as the area was well established with a lengthy monitoring history.

16. Overall Assessment

Fishery

Two sites were identified within the Loch Eishort production area, both of which lie in the upper portion of the loch. The site listed in the 2014/15 FSAS classification document as Drumfearn was identified by the harvester as being Site 1 North. A second site, Morsaig, was identified to the southwest of Site 1 North and is owned by a separate harvester, Robert Kelly. Common mussels are cultured on double-headed longlines with 7-metre droppers at both sites.

Human sewage impacts

The principal human sewage impacts to the production area come from septic tank discharges from private homes located at Heaste and Drumfearn. No discharges were observed from the 25 homes noted at Heaste during the shoreline survey. SEPA reported information on 9 consented discharges in this area, all but one of which were consented to discharge to soakaway. The remaining consent identified a discharge to Allt an Daraich. The discharges to soakaway all lay along the Allt na Heaste and any malfunction or rerouting of these would be most likely to impact that watercourse, which discharges to the loch northwest of the mussel farms.

A floating jetty and anchorage are also located in Loch an Eilean, south of Heaste. Six fishing boats and a yacht were observed in this area during the shoreline survey, indicating the possibility of overboard discharges from boats contributing to faecal indicator loads in the area. It is not known what times of year the floating jetty is present. However, as a temporary structure it could be moved at any time.

The majority of properties at Drumfearn appear to lie just outside the Loch Eishort catchment and therefore any associated septic tank discharges would not be expected to have a material impact at the mussel farms. Four homes were observed during the shoreline survey at Drumfearn, but no discharge pipes were noted. SEPA records identified one property with consent to discharge to sea at this location, although the outfall pipe was not seen during the shoreline survey.

Discharges from the Drumfearn area lie closest to the mussel farms, particularly the southern edge of Site 1 North and the north-eastern end of Morsaig.

Agricultural impacts

The main agricultural impacts will be from livestock kept on crofts at Heaste and Drumfearn. The larger number of animals was seen around Heaste, where the agricultural land all appears to lie within the catchment of the loch. Faecal contamination from this source is most likely to be carried to the present production area via Allt na Heast, which discharges into Loch an Eilean 1.7 km northwest of the the Morsaig mussel farm.

Much of the agricultural land at Drumfearn appears to lie along the Alltant-Slugain and Lòn Creadha, which flow into Loch na Dal, east of Loch Eishort. Diffuse contamination arising from this land is not considered likely to impact water quality at the mussel farms. However, a small number of sheep were seen near the shoreline east of the mussel farms, and any livestock kept here would be expected to contribute to diffuse faecal contamination in the vicinity of the mussel farms, particularly the eastern edge of Site 1 North and the north-eastern end of Morsaig.

Wildlife impacts

Wildlfe are expected to contribute to be the main contributors to background levels of contamination found in most of the watercourses discharging to the loch and particularly Abhainn Ceann Loch Eiseoirt, which is the principal freshwater input to the loch. Seabirds are known to breed on islands to the west of the mussel farms, and the intertidal areas around the head of the loch are likely to attract wading birds. Small numbers of gulls and wading birds were seen during the shoreline survey. Watercourses in the area are also likely to carry faecal contamination from deer and other wild mammals. There was insufficient information upon which to base either a temporal or spatial assessment of potential impact from these sources.

Seasonal variation

Seasonal variation is expected in human population in the area due to the presence of visitor accommodation and possible holiday homes in the area. Rainfall tends to be higher in winter, with a relatively dry period occurring in summer. There is likely to be seasonal variation in the types and numbers of birds found around the fishery, however there was insufficient information on which to assess how it might impact on the bacteriological quality of the shellfish at the two mussel farms.

No significant seasonal variation was seen in average (geometric mean) historical *E. coli* monitoring results, although all results ≥230 *E. coli* MPN/100 g occurred in July, August and October.

Rivers and streams

A large number of watercourses discharge into the production area. The largest input to the head of the loch is from the Abhainn Ceann Loch Eiseoirt, which drains a steep, hilly area of bog and rough heath. Seawater samples taken at the east end of the mussel farms and from shore where the loch narrows west of the river mouth showed very low or undetectable levels of *E. coli*, suggesting that any input from this river was low and/or significantly diluted at the time of shoreline survey. Any faecal contamination to this river is likely to be from wildlife sources. Livestock were observed grazing in the catchments of the watercourses numbered 2 and 5.

Of the watercourses recorded and sampled during the shoreline survey, the highest loading were from those located around Loch an Eilean, where there was the

greatest concentration of homes and livestock within the catchment. Loch an Eilean lies approximately 1.7 km northwest of Site 1 North, and contaminants from this source could potentially impact the western side of the site.

Movement of contaminants

The hydrographic assessment showed that subsurface water flows were likely to transport contaminants up-loch from sources within Loch an Eilean and toward the mussel farms. The estimated cumulative transport distance on each phase of the tide is 1.7km, taking contaminants as far as Site 1 North. In shoreline survey sampling, the only shellfish *E. coli* result greater than 20 MPN/100g was obtained from a sample taken from the southwestern half of the mussel site, within reach of sources at Heaste.

Although the waters of the loch are expected to be well mixed under windy conditions, after heavy rainfall and calm conditions a clearly stratified surface layer of reduced salinity is likely to form.

Temporal and geographical patterns of sampling results

Many of the sample results were reported against the nominal RMP, which lies approximately 100 m from the current mussel farm and seabed lease at Site 1 North. It is not entirely clear where samples attributed to this location have been. It is presumed that these samples were all taken from somewhere on the mussel farms. Therefore, it was not possible to undertake a meaningful spatial assessment of results in this instance. Sample results were more variable and higher prior to the end of 2012, when a result of 5400 *E. coli* MPN/100 g occurred on 09/10/2012. Since that time, results have all been below the limit of detection with the exception of a single result of 130 *E. coli* MPN/100 g on 14/05/2013. The reason for this sudden change in pattern is not clear.

Conclusions

Overall, contamination levels in the loch are likely to be low. There have been episodic results > 230 E. coli MPN/100 g, including one result >4600. However, results since 2013 have been largely below the limit of detection, though it is not clear whether this is due to changes in sampling locations or other factors.

As much of the monitoring history has been attributed to an RMP that does not lie on the active fishery, it was not possible to draw conclusions regarding the spatial distribution of results in relation to the shellfish farms.

Faecal contamination sources, aside from diffuse contamination arising from wildlife, are concentrated around Heaste and Drumfearn. There is likely to be a greater contribution at Heaste, however Drumfearn lies much closer to the shellfish farms

and therefore any contamination arising from this are may be more likely to impact the water quality at the shellfishery.

Predicted contaminant transport suggests that only sources less than 2 km from the mussel farms will have an impact on the water quality at those locations (over a single phase of a tidal cycle) and therefore sources at Drumfearn are likely to have a greater impact than sources at Heaste.

Although there was no statistically significant correlation between season and results, the highest results occurred during the months of July, August and October suggesting monthly rather than strictly seasonal variation in results.

17. Recommendations

Production area

It is recommended that the production area boundaries be curtailed to exclude the upper and lower loch areas not used for shellfish production and to exclude Loch an Eilean, which receives diffuse agricultural and human faecal contamination via the watercourses that flow into it.

It was not possible to exclude the consented discharge to the loch identified by SEPA at Drumfearn.

The recommended boundaries are:

> The area bounded by lines drawn from NG 6704 1669 to NG 6716 1651 and from NG 6569 1615 to NG 6569 1531 and extending to MHWS.

RMP

It is recommended that the RMP be amended to reflect the monitoring point identified on the mussel farm during the shoreline survey, at NG 6644 1628. This location lies near the northwest extent of the farm and should reflect contamination coming up the loch from sources around Loch an Eilean as well as any wildlife source contamination coming down the loch from Abhainn Ceann Loch Eiseoirt. It is recommended that bagged shellfish be placed on the long line nearest this point to ensure that samples can be taken from the RMP location at any time. Any bagged shellfish used should be placed at the RMP at least two weeks prior to sampling to ensure they are representative of water quality conditions at that location.

Tolerance

The recommended sampling tolerance is 40 m to allow for some movement of the mussel lines. Due to reported problems with spat settlement it is recommended that bagged shellfish be place at the RMP to facilitate sampling. Any bagged shellfish used must be in place at least a fortnight prior to sampling to allow sufficient time for the animals to acclimate and become representative of conditions at the monitoring point.

Depth of sampling

Most sources of contamination to the area are likely to be carried in surface water flow from watercourses, or potentially directly deposited at the surface by seabirds, therefore it is recommended that samples be taken from the top 1-3 metres of the lines.

Frequency

As there was some evidence of variation in sampling results by month, with higher results coinciding with anticipated summer increases in human and livestock populations, it is recommended that monthly monitoring be maintained.

The recommended RMP and production area boundaries are shown on a map in Figure 17.1.

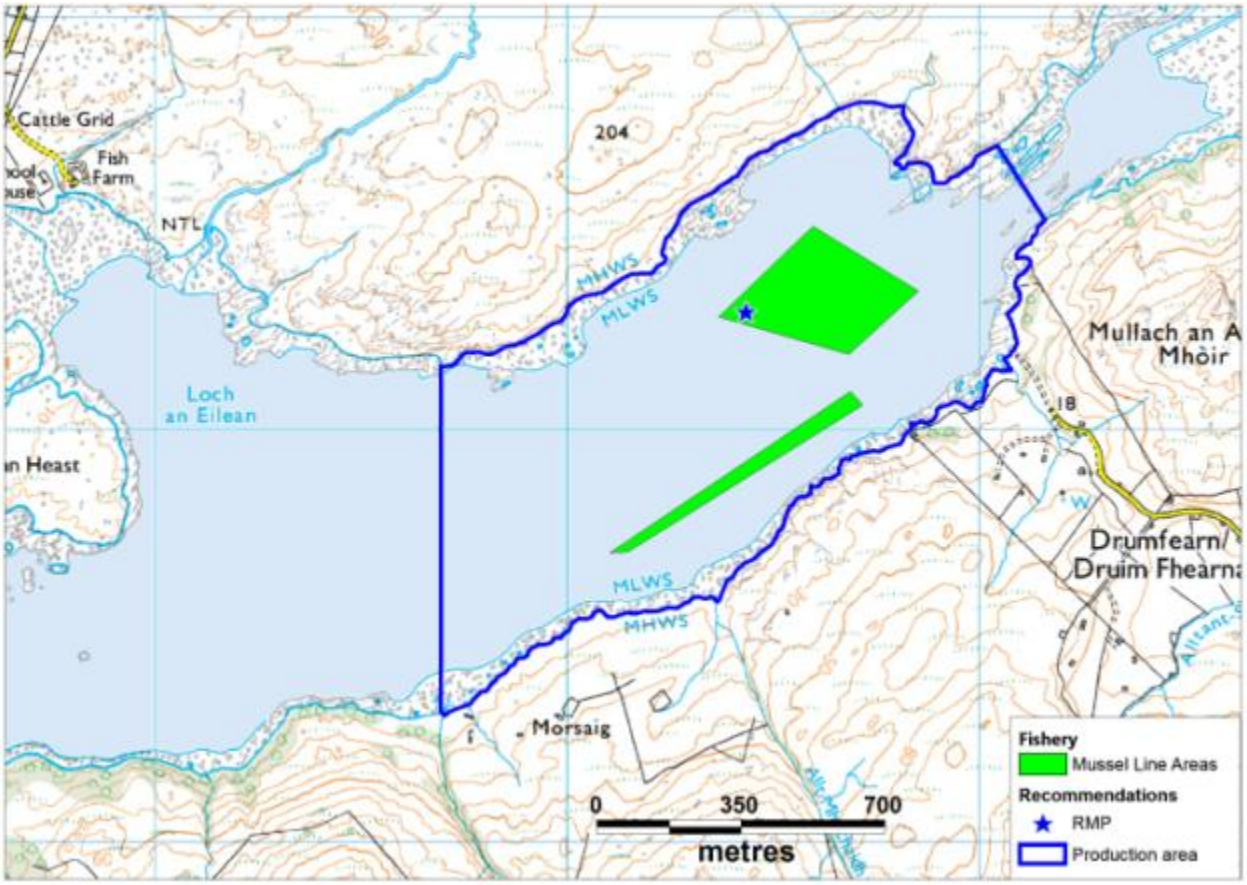


Figure 17.1 Map of recommendations at Loch Eishort

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19. List of Figures and Tables

Appendices

1. **General Information on Wildlife Impacts**
2. **Tables of Typical Faecal Bacteria Concentrations**
3. **Statistical Data**
4. **Hydrographic Section Glossary**
5. **Shoreline Survey Report**
6. **Shoreline Survey Adendum**
7. **SEPA Discharge Consents**
8. **CTD Data**

1. General Information on Wildlife Impacts

Pinnipeds

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

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

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

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

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

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

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

Cetaceans

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

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

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

Birds

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

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

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

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

Deer

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

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

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

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

Other

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

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

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2. Tables of Typical Faecal Bacteria Concentrations

Summary of faecal coliform concentrations (cfu $100ml^{-1}$) for different treatment levels and individual types of sewage-related effluents under different flow conditions: geometric means (GMs), 95% confidence intervals (CIs), and results of t-tests

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

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

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

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

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

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

Table 4 - Comparison of faecal indicator concentrations (average numbers/g wet weight) excreted in the faeces of warm-blooded animals

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

Source: (Gauthier & Bedard, 1986)

References

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3. Statistical Data

Descriptive statistics

One-way ANOVA: logec versus Season

Method

Null hypothesis All means are equal

Alternative hypothesis At least one mean is different

Significance level α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Season	4	1, 2, 3, 4

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Season	3	1.950	0.6501	1.87	0.145
Error	61	21.257	0.3485		
Total	64	23.207			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.590312	8.40%	3.90%	0.00%

Means

Season	N	Mean	StDev	95% CI
1	17	1.1952	0.3604	(0.9089, 1.4815)
2	17	1.513	0.791	(1.227, 1.799)
3	14	1.461	0.771	(1.146, 1.777)
4	17	1.1062	0.2999	(0.8200, 1.3925)

Pooled StDev = 0.590312

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Season	N	Mean	Grouping
2	17	1.513	A
3	14	1.461	A
1	17	1.1952	A
4	17	1.1062	A

Means that do not share a letter are significantly different.

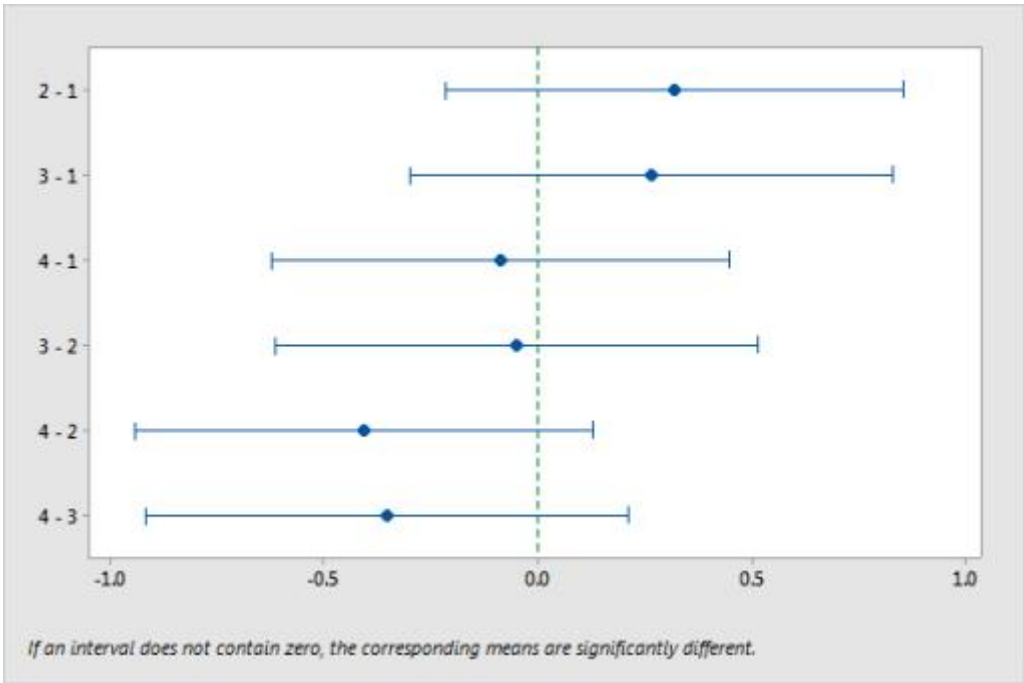

Figure 1 Differences in Means of LogEC from Tukey Simultaneous 95% CIs test

4. Hydrographic Assessment Glossary

The following technical terms may appear in the hydrographic assessment.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5. Shoreline Survey Report

Shoreline Survey Report

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

Document Number	B0067_Shoreline 0029

Revision History

Revision	Changes	Date
A	Issue for internal review	08/05/2014
B	Second version for internal review/approval	14/05/2014
01	First formal issue to Cefas	20/05/2014
02	Second formal issue to client with corrections	19/06/2014
03	Third issue resolving comments on issue 02	19/06/2014

	Name & Position	Date
Author	Debra Brennan & Eilidh Cole	06/05/2014
Checked	Andrea Veszelovszki,	19/06/2014
Approved	John Hausrath	19/06/2014

SRSL, Scottish Marine Institute, Oban, Argyll, PA37 1QA, tel 01631 559 470, www.samsrsl.co.uk

Production area:	Loch Eishort Mussel Culture
Site name(s):	Site 1 North (Mr Duncan Henderson) Morsaig Site (Mr Robert Kelly)
SIN:	SL-137-281-08
Species:	Common Mussel
Harvester(s):	Mr Peter MacAskill and Mr Robert Kelly (operator: Mr Duncan Henderson)
Local Authority:	Highlands Council: Skye and Lochalsh
Status:	Existing area
Date Surveyed:	28-April-2014
Surveyed by:	Debra Brennan, Eilidh Cole
Existing RMP:	NG 6641 1614

Area Surveyed

Approximately 1.5km of shoreline on the south side of the loch and production area, and a short 0.3km section of the road running from Drumfearn down to the loch were surveyed. Also approximately 1.3km of shoreline on the north side of the loch directly below the hamlet of Heaste and to the northwest of the production area was surveyed.

Specific observations made during the survey are mapped in Figure 1 and listed in Table 1. Water and shellfish samples were collected at the locations marked on Figure 2. Bacteriology results are given in Tables 2 and 3. Photographs are presented in Figures 3-12.

Weather

There was no rainfall recorded in the 48 hours prior to survey.

On the day of the survey the weather was dry and mostly sunny with some clouds and haze. Temperature ranged between 14-16 °C with wind speed of F1-2 of northerly direction. Sea state: slight.

Stakeholder engagement during the survey

Prior to survey, during the preparation both the harvester, Mr. Peter MacAskill, and the local sampling officer, Mr. Allan MacDonald, were very helpful and provided information.

On the survey day the team met up with the harvester, Mr. MacAskill, on-site and he provided further detailed information about the site's past, future, and current, ongoing works.

Mr. MacDonald also met up with the team and assisted with the collection of shellfish samples and provided detail on the RMP and other information concerning the site and the loch in general.

Mr. Robert Kelly was not available on the day of the survey but had given permission for Mr MacAskill to take the team to his site to collect samples.

Fishery

The production area at Loch Eishort is situated at the head of the loch and is approximately 4.8km in length in total. There are two sites owned by separate owners both cultivating Common mussels (*Mytilus edulis*).

Mr. Peter MacAskill, the owner of the larger site closer to the head of the loch, has owned his site for over 30 years and is hoping to extend his farm in the future. Mr. MacAskill's site (Site 1 North), has thirteen long lines with droppers that extend to 7m in length. Five of these lines have mature mussels and the other eight lines only have spats.

The production area is harvested year round, and all produce is sold either locally to hotels and restaurants or to supermarkets in the UK, none of the mussels are exported.

Most of the lines are spat lines and the harvester informed the survey team that it has been difficult to get the spat to settle over the last couple of years and production of mature mussels over the last 12-18 months has been lower than in previous years.

Mr Robert Kelly's site (the Morsaig site) consists of six long lines also with 7m droppers, however there were no mussels at depth on these droppers, therefore mussel samples were obtained from the surface of the mussel lines.

Sewage Sources

The shellfish farms are located at the head of the loch where the shoreline surrounding it is largely uninhabited. The small hamlet of Heaste is situated approximately 1.5km down the loch on the northwest side of the production area. There are approximately 25 private dwellings on the hillside above the loch, two of which are close to the shoreline. All properties were checked where possible for outflows, pipes and septic tanks. There were no pipes visible on the shoreline or running to the watercourses in the area.

On the south side of the loch at Drumfearn there were approximately four private dwellings on the hillside above the loch, none close to the shoreline. One of the dwellings was a small farm/croft and eight sheep were observed on the shoreline (see farming and livestock below).

The surveyed shore was largely undisturbed from its natural state beyond its use as a production site, with no evidence of sewage outflows discovered during the survey.

Seasonal Population

There were no hotels, B&B's or caravan sites around the loch.

Boats/Shipping

The shore at Heaste had a floating jetty. On the day of the survey six fishing boats and one yacht were observed in the water.

Farming and Livestock

Eight sheep were observed by a small farm/croft near Drumfearn on the south side of the loch. There were fourteen cattle grazing on the grassy shoreline close to Heaste, on the north side of the loch, with eight sheep in the same area.

Fifteen sheep were also observed on the island of Eilean Heaste from the shoreline during the survey.

Land Use

The shoreline surrounding the production area was predominantly wild, natural land. Small areas were used for sheep and cattle grazing.

Land Cover

The shore was rocky and pebbly, the hillside gradually rose away from shore and most of the shoreline was accessible at low tide. The land surrounding the loch was rough tussocky grass with rocky outcrops. Sparse native tree cover was observed, mostly birch.

Watercourses

Six of the watercourses displayed on the survey map were to be sampled. Two of these were on the south shore; Allt Mhochaldh and one unnamed; four on the north shore; Allt Lon Bhuidhe, Allt an Daraich, Allt Bealach a' Choiridh Losall and Allt Murchaidh. All of these watercourses were observed and sampled successfully. No additional watercourses were observed during the survey.

Due to issues with the sampling during the shoreline survey, all watercourses sampled were to be revisited and new samples and measurements taken, with results to be reported in an addendum to this report.

Wildlife/Birds

Four Common gulls (*Larus canus*), three oystercatchers (*Haematopus ostralegus*), four cormorants (*Phalacrocorax carbo*) and three grey herons (*Ardea cinerea*) were observed during the survey.

There was a dead, decomposing whale on the shore, approximately 3-4m in length, in the survey area close to Heaste, the local sampling officer had previously informed the team that it was possibly a Pilot whale (*Globicephala* sp.). An email from the SRUC Veterinary Services later confirmed that it was a Long Finned Pilot Whale.

No other wildlife was observed during the survey.

Figure 1. Loch Eishort waypoints

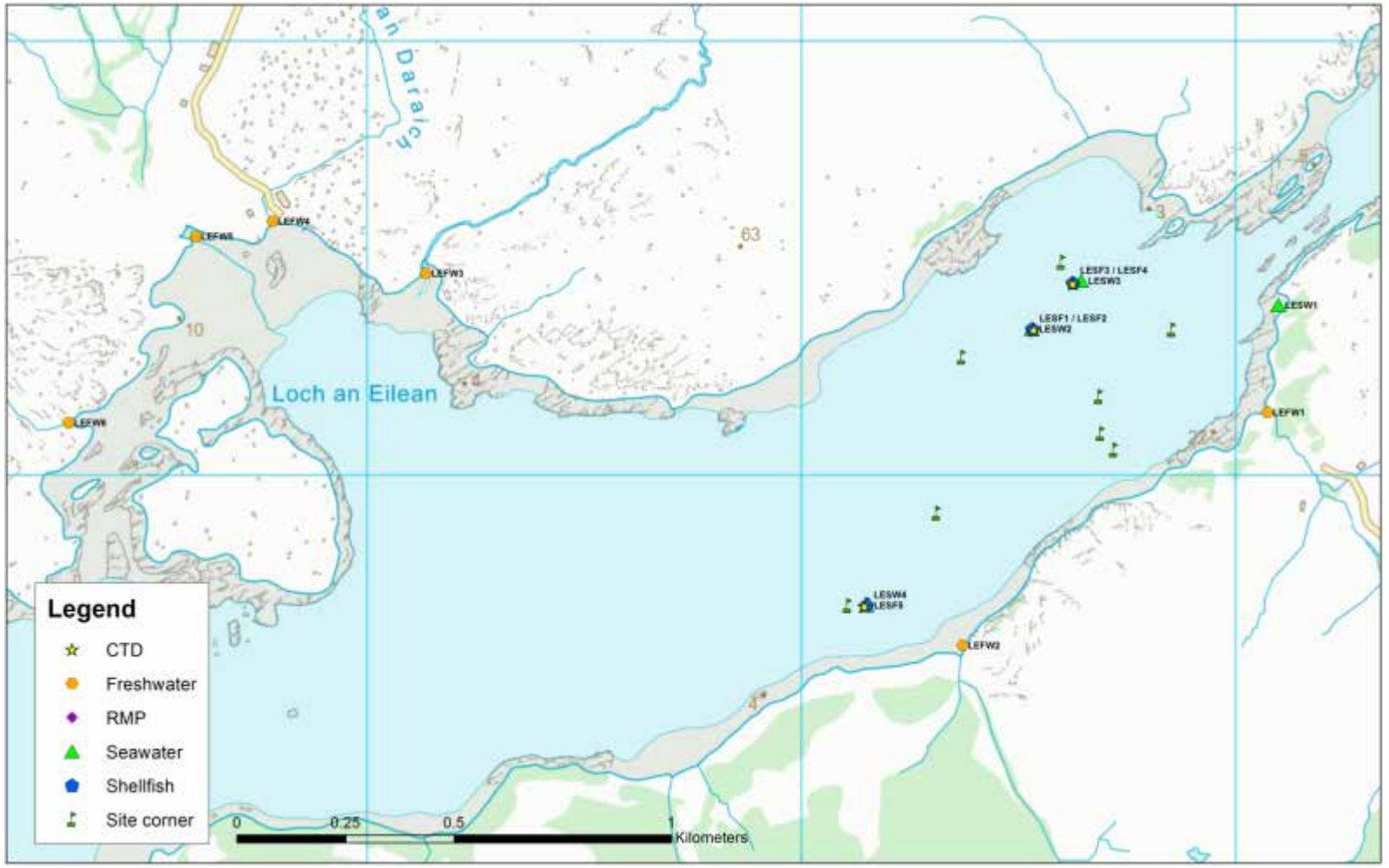

Figure 2. Loch Eishort samples

Table 1 Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
1	28/04/2014	9:33	NG 67188 16028	167189	816029			Start of survey on the south side of Loch Eishort.
2	28/04/2014	9:51	NG 67097 16391	167098	816391	Fig 3	LESW1	Planned seawater sample LESW1.
3	28/04/2014	10:03	NG 67072 16144	167073	816144		LEFW1	Planned freshwater sample LEFW1.
4	28/04/2014	10:04	NG 67072 16144	167072	816145	Fig 4		Observations associated with waypoint 3. Watercourse running from hillside over rocky shore into loch. Width 91cm, Depth 9cm, Flow 0.086m/s; SD 0.005. Eight sheep observed in area surrounding watercourse.
5	28/04/2014	10:57	NG 66370 15608	166371	815608		LEFW2	Planned freshwater sample LEFW2.
6	28/04/2014	10:58	NG 66370 15608	166370	815608	Fig 5		Observations associated with waypoint 5. Watercourse running over shore into loch close to production area. Width 1m; Depth 24cm; Flow 0.03m/s; SD 0.015. Four Common gulls and two oystercatchers, four cormorants and three herons were observed.
7	28/04/2014	11:58	NG 66529 16331	166530	816332			Confirmed location of RMP.
8	28/04/2014	12:00	NG 66530 16336	166531	816337		LESW2	Planned seawater sample LESW2.
9	28/04/2014	12:01	NG 66531 16336	166532	816337		LESF1 / LESF2	Planned Shellfish samples LESF1 from top of dropper, LESF2 from bottom of dropper, 7m depth.
10	28/04/2014	12:08	NG 66534 16334	166534	816334			CTD cast.
11	28/04/2014	12:21	NG 66369 16271	166369	816272			NW limit of first set of mussel lines.
12	28/04/2014	12:23	NG 66598 16490	166598	816491	Fig 6		NE limit of mussel lines.
13	28/04/2014	12:26	NG 66853 16335	166853	816335			SE limit of mussel lines.
14	28/04/2014	12:29	NG 66685 16180	166685	816181			SW limit of mussel lines.
15	28/04/2014	12:40	NG 66643 16447	166644	816447		LESW3	Planned seawater sample LESW3.
16	28/04/2014	12:42	NG 66625 16443	166626	816443		LESF3 / LESF4	Planned shellfish samples LESF3 from top of dropper, LESF4 from bottom of dropper, 7m depth.
17	28/04/2014	12:45	NG 66624 16440	166625	816441			CTD cast.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
18	28/04/2014	12:52	NG 66688 16095	166689	816096			NE limit of second set of mussel lines.
19	28/04/2014	12:53	NG 66718 16057	166719	816058			SE limit of mussel lines.
20	28/04/2014	12:59	NG 66105 15699	166106	815700			NW limit of first set of mussel lines.
21	28/04/2014	13:00	NG 66149 15702	166150	815703			SW limit of mussel lines.
22	28/04/2014	13:01	NG 66150 15700	166151	815700		LESW4	Planned seawater sample LESW4.
23	28/04/2014	13:01	NG 66150 15699	166150	815700		LESF5	Planned shellfish sample LESF5 from top of line, no dropper on this line.
24	28/04/2014	13:05	NG 66144 15697	166145	815698			CTD Cast.
25	28/04/2014	13:09	NG 66310 15912	166311	815912			North coordinate midpoint.
26	28/04/2014	16:48	NG 65135 16464	165135	816464			Start of survey on north side of Loch Eishort.
27	28/04/2014	16:50	NG 65137 16464	165138	816465			Waypoint for initial sampling of LEFW3, but retaken on 30/04/14 (see waypoint 36). See comment under sampling section.
28	28/04/2014	16:50	NG 65137 16464	165137	816464	Fig 7		Observations associated with waypoint 36. Watercourse from hillside into loch. Width; 5m; Depth 1- 22cm; Flow 1- 0.025m/s; SD 0.005; Depth 2- 22cm, Flow 2- 0.01m/s; SD 0.002.
29	28/04/2014	16:59	NG 65003 16452	165004	816452	Fig 8		Dead whale on shore, decomposing.
30	28/04/2014	17:05	NG 64783 16580	164783	816581			Waypoint for initial sampling of LEFW4, but retaken on 30/04/14 (see waypoint 37). See comment under sampling section.
31	28/04/2014	17:06	NG 64783 16582	164783	816582	Fig 9 & 10		Observations associated with waypoint 37. Watercourse from hillside running by small residential area into loch. Width 5m; Depth 11cm; Flow 0.032m/s; SD 0.003. Two houses on shoreline, jetty into loch, six fishing boats, one small yacht.
32	28/04/2014	17:18	NG 64605 16544	164605	816544			Waypoint for initial sampling of LEFW5, but retaken on 30/04/14 (see waypoint 38). See comment under sampling section.
33	28/04/2014	17:20	NG 64604 16543	164605	816544	Fig 11		Observations associated with waypoint 38. Watercourse running through small wooded glen. Width 495cm; Depth 1- 20cm; Flow 0.09m/s; SD 0.015; Depth 2- 27cm; Flow 0.011m/s; SD 0.004. Eight sheep on grassy shoreline, fourteen cows.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
34	28/04/2014	17:40	NG 64312 16118	164313	816119			Waypoint for initial sampling of LEFW6, but retaken on 30/04/14 (see waypoint 39). See comment under sampling section.
35	28/04/2014	17:41	NG 64314 16119	164314	816120	Fig 12		Observations associated with waypoint 39. Watercourse running down small rocky gorge to shore. Width 1.75cm; Depth 18cm; Flow 0.014; SD 0.002. End of Loch Eishort survey.
36	30/04/2014	9:22	NG 65135 16464	165135	816465		LEFW3	Planned freshwater sample LEFW3.
37	30/04/2014	9:32	NG 64781 16584	164782	816585		LEFW4	Planned freshwater sample LEFW4.
38	30/04/2014	9:38	NG 64605 16549	164605	816549		LEFW5	Planned freshwater sample LEFW5.
39	30/04/2014	9:52	NG 64312 16120	164313	816121		LEFW6	Planned freshwater sample LEFW6.

Photographs referenced in the table can be found attached as Figures 3-12.

Sampling

Four seawater and six freshwater samples were collected at the sites marked in Figure 2.

Five mussel samples were taken, two from two depths from Peter MacAskill's site (top of dropper and 7m depth, in accordance with the agreed sampling protocols) and one from the top of the dropper of Robert Kelly's site but there were no mussels of the right size at the bottom of the line.

All the samples were transferred to two Biotherm 30 boxes with ice packs and posted to Glasgow Scientific Services (GSS) for *E.coli* testing, on the day of collection* and were received by the laboratory the following day. The sample temperatures on arrival at the laboratory were recorded as 4.8 and 7.1°C.

*Four freshwater samples were taken late afternoon on the 28/04/14 (WP27, 30, 32 & 34), it was expected that these samples would be sent the following day with the samples from Loch Slapin at 3pm; this would have meant they would have arrived at GSS within the 48 hour allocated cut-off period. However the 3pm deadline for the post office was missed on the 29/04/14 due to a problem with the shoreline survey regarding access to the road. The four freshwater samples were discarded and collected afresh on the 30/04/14 (WP 36-39), they were posted to GSS the same day and received by the laboratory the following day.

Due to the misidentification of four of the freshwater samples as contaminated, the watercourses will be remeasured and sampled at a later date and these results will be issued as an addendum to the shoreline survey report.

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

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

Table 2. Water Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (cfu/100ml)	Salinity (ppt)
1	28/04/14	LEFW1	NG 67072 16144	Freshwater	<10	
2	28/04/14	LEFW2	NG 66370 15608	Freshwater	<10	
3	30/04/14	LEFW3	NG 65135 16464	Freshwater	<1000	
4	30/04/14	LEFW4	NG 64781 16584	Freshwater	<1000	
5	30/04/14	LEFW5	NG 64605 16549	Freshwater	<1000	
6	30/04/14	LEFW6	NG 64312 16120	Freshwater	<1000	
7	28/04/14	LESW1	NG 67097 16391	Seawater	0	34.33
8	28/04/14	LESW2	NG 66530 16336	Seawater	1	33.60
9	28/04/14	LESW3	NG 66643 16447	Seawater	0	33.60
10	28/04/14	LESW4	NG 66150 15700	Seawater	0	33.60

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (MPN/100g)
1	28/04/14	LESF1	NG 66531 16336	Common Mussel	330
2	28/04/14	LESF2	NG 66531 16336	Common Mussel	<18
3	28/04/14	LESF3	NG 66625 16443	Common Mussel	20
4	28/04/14	LESF4	NG 66625 16443	Common Mussel	<18
5	28/04/14	LESF5	NG 66150 15699	Common Mussel	<18

CTD Profiles

CTD profiles were taken at three locations in the production area, at each sampling point around the mussel lines (refer to Figure 2 for map locations). The gathered data will be sent to client as a separate document.

Photographs – NOTE that camera clock was still set to GMT at time of survey therefore time printed on photos is an hour behind real time.

Figure 3. Peter MacAskills Common mussel farm Waypoint 2. Location of LESW1.

Figure 4. Watercourse from South of loch showing mussel lines in the background. Waypoint 4. Location of LEFW1.

Figure 5. Watercourse running from hillside below Drumfearn Waypoint 6. Location of LEFW2.

Figure 6. Looking back towards Drumfearn. Waypoint 12.

Figure 7. Watercourse entering the loch North West of production area Waypoint 28. Location of LEFW3.

Figure 8. Dead whale on shore close to Heaste. Waypoint 29.

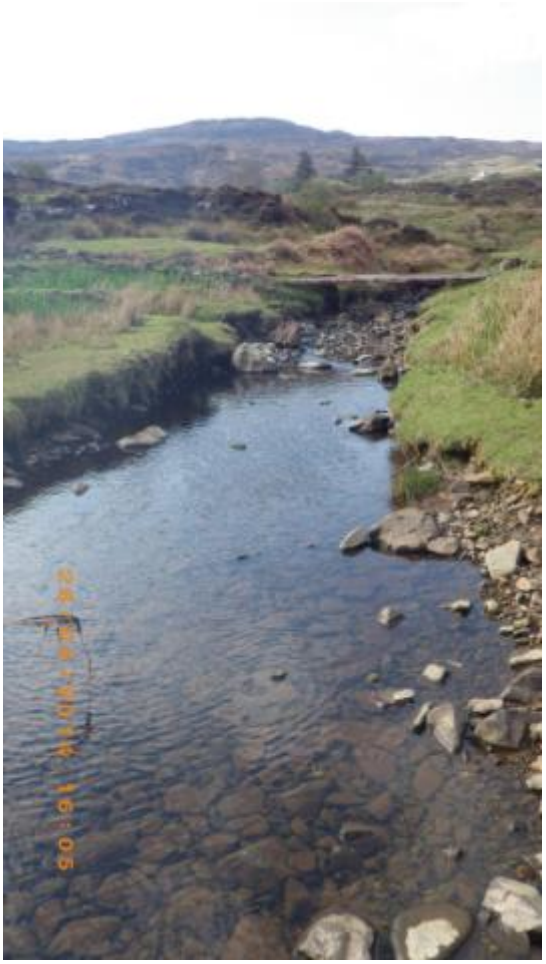

Figure 9. Watercourse running through hamlet of Heaste onto shore. Waypoint 31. Location of LEFW4.

Figure 10. Floating jetty and boats to North West of production area. Waypoint 31. Location of LEFW4.

Figure 11. Watercourse running through grassy area onto shore. Waypoint 33. Location of LEFW5.

Figure 12. Watercourse running through small gorge onto shore. Waypoint 35. Location of LEFW6.

6. Shoreline Survey Addendum

Report Title	Loch Eishort Shoreline Survey Report
Project Name	Shellfish Sanitary Surveys
Client/Customer	Cefas
SRSL Project Reference	00561_B0067
Document Number	B0067_Shoreline 0029 – Addendum report to original report after resampling of watercourses

R
evision History

Revision	Changes	Date
A	Issue for internal review	25/06/2014
B	Second issue for internal review	30/06/2014
01	First formal issue to Cefas	30/06/2014

	Name & Position	Date
Author	Debra Brennan & Eilidh Cole	25/06/2014
Checked	Andrea Veszelovszki,	30/06/2014
Approved	Andrea Veszelovszki	30/06/2014

SRSL, Scottish Marine Institute, Oban, Argyll, PA37 1QA, tel 01631 559 470, www.samsrsl.co.uk

Production area:	Loch Eishort Mussel Culture
Site name(s):	Site 1 North (Mr Duncan Henderson) Morsaig Site (Mr Robert Kelly)
SIN:	SL-137-281-08
Species:	Common Mussel
Harvester(s):	Mr Peter MacAskill and Mr Robert Kelly (operator: Mr Duncan Henderson)
Local Authority:	Highlands Council: Skye and Lochalsh
Status:	Existing area
Date Surveyed:	28/04/2014
Surveyed by:	Debra Brennan, Eilidh Cole
Existing RMP:	NG 6641 1614

Area Surveyed

This is an addendum to the original report of the survey completed on the 28th April 2014. All freshwater sites were resampled on the 17th June 2014. All new observations are recorded in Table 1 and new sample results recorded in Table 2.

Weather

There was no rainfall recorded in the 48 hours prior to survey.

On the day of the survey the weather was dry with temperatures around 20°C. There was a very light north-westerly breeze. Cloud cover was approximately 10%. Sea state was calm.

Table 1 Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
1	17/06/2014	15:18	NG 66357 15621	166358	815622			Start of survey at Loch Eishort.
2	17/06/2014	15:20	NG 66374 15598	166374	815598	Figure 3	LEFW1	Planned freshwater sample taken opposite mussel lines at Loch Eishort on the south shore from Allt Mhochaidh.
3	17/06/2014	15:21	NG 66374 15598	166374	815599	Figure 3		Watercourse running onto shore. Width - 2m 83cm; Depth 1 - 11cm; Flow 1 - 0.005 m/s; SD 1 - 0.006. Depth 2 - 13 cm; Flow 2 - 0.077 m/s; SD 2 - 0.006. Associated with waypoint 2.
4	17/06/2014	15:47	NG 67073 16146	167074	816147	Figure 4	LEFW2	Planned freshwater sample taken from shore at Drumfearn.
5	17/06/2014	15:48	NG 67076 16148	167077	816149	Figure 4		Watercourse running onto shore with Drumfearn behind. Width - 83 cm; Depth - 8 cm; Flow - 0.020 m/s; SD - 0.005. Associated with waypoint 4.
6	17/06/2014	17:20	NG 65136 16462	165136	816462	Figure 5	LEFW3	Planned freshwater sample on the north shore of the loch from Allt Lon Bhuidhe by Heaste.
7	17/06/2014	17:20	NG 65135 16461	165136	816462	Figure 5		Watercourse running onto shore. Width - 6m 26cm; Depth 1 - 16 cm; Flow 1 - 0.009 m/s; SD 1 - 0.007 (east bank). Depth 2 - 19 cm; Flow 2 - 0.011 m/s; SD 2 - 0.004 (west bank). Associated with waypoint 6.
8	17/06/2014	17:37	NG 64782 16583	164782	816584	Figure 6	LEFW4	Planned freshwater sample on north shore next to house below road from Allt na Daraich.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
9	17/06/2014	17:37	NG 64782 16583	164782	816584	Figure 6		Watercourse running onto shore with house behind. Width - 3m 27 cm; Depth 1 - 24 cm; Flow 1 - 0.006 m/s; SD 1 - 0.003. Depth 2 - 24 cm; Flow 2 - 0.003 m/s; SD 2 - 0.002. Associated with waypoint 8.
10	17/06/2014	17:49	NG 64605 16548	164606	816549	Figure 7	LEFW5	Planned freshwater sample from north shore from Allt na Heast watercourse.
11	17/06/2014	17:49	NG 64605 16548	164606	816549	Figure 7		Watercourse running onto shore. Width – 7m 39 cm; Depth 1 – 35 cm; Flow 1 – 0.003 m/s; SD 1 – 0.003. Depth 2 – 10 cm; Flow 2 – 0.095 m/s; SD – 0.003. Associated with waypoint 10.
12	17/06/2014	18:08	NG 64327 16124	164327	816125		LEFW6	Planned freshwater sample opposite Eilean Heaste Island from watercourse Allt Mhurchaidh.
13	17/06/2014	18:08	NG 64327 16125	164328	816126			Small watercourse running onto shore. Width – 1m 03cm; Depth – 14 cm; Flow – 0.020 m/s; SD – 0.009. Associated with waypoint 12.

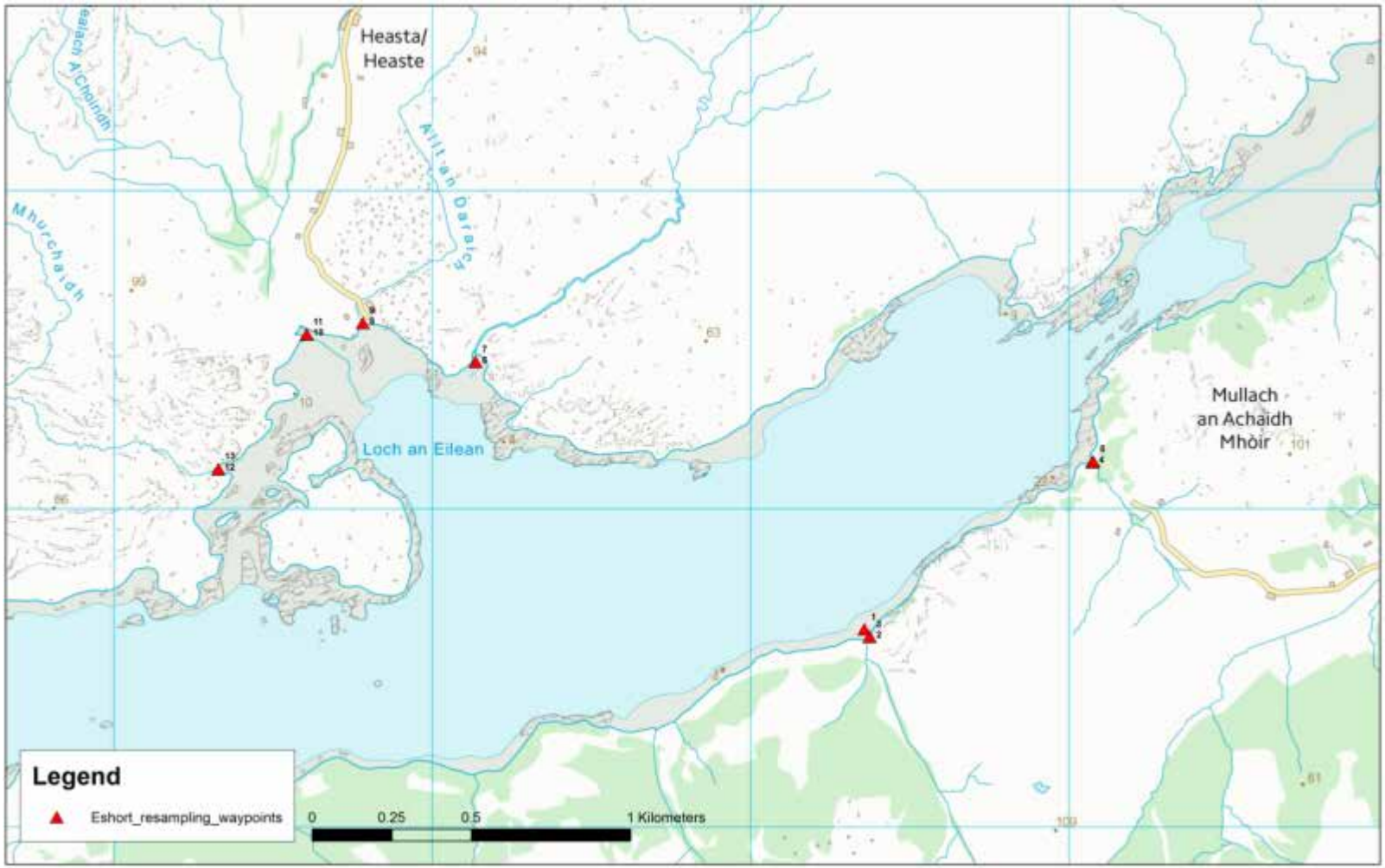

Figure 1. Loch Eishort Waypoints (resampling).

Figure 2. Loch Eishort Samples (resampling).

Sampling

Freshwater samples were re-sampled and collected at the sites marked in Figure 2.

Due to the misidentification of the freshwater samples as contaminated from the previous survey, the watercourses were re-measured and sampled. The results presented below are from the repeat sampling.

All the samples were transferred to a Biotherm 30 box with ice packs and posted to Glasgow Scientific Services (GSS) for *E.coli* analysis on the following day and were received by the lab the day after posting. The sample temperature on arrival at GSS was 1.7°C.

Table 2. Water Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (cfu/100ml)	Salinity (ppt)
1	17/06/2014	LEFW1	NG 66374 15598	Freshwater	<10	-
2	17/06/2014	LEFW2	NG 67073 16146	Freshwater	100	-
3	17/06/2014	LEFW3	NG 65136 16462	Freshwater	130	-
4	17/06/2014	LEFW4	NG 64782 16583	Freshwater	<10	-
5	17/06/2014	LEFW5	NG 64605 16548	Freshwater	200	-
6	17/06/2014	LEFW6	NG 64327 16124	Freshwater	20	-

Photographs

Figure 3. Watercourse running onto shore opposite mussel lines on south shore of loch. Associated with waypoints 2 & 3. Location of freshwater sample LEFW1.

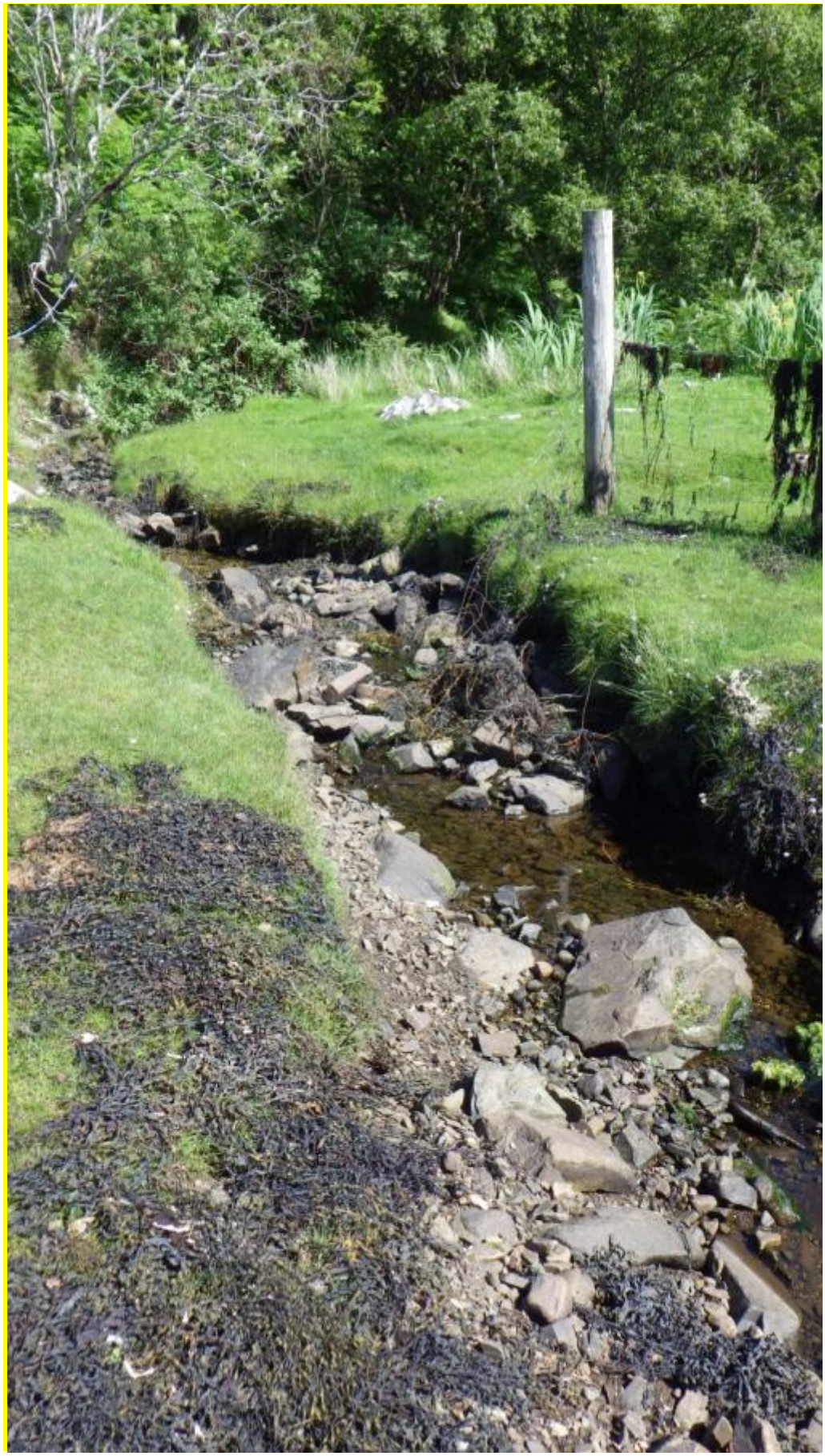

Figure 4. Watercourse running onto shore with Drumfearn behind. Associated with waypoints 4 & 5. Location of freshwater sample LEFW2.

Figure 5. Watercourse running onto north shore. Associated with waypoints 6 & 7. Location of freshwater sample LEFW3.

Figure 6. Watercourse running onto shore with house behind. Associated with waypoints 8 & 9. Location of freshwater sample LEFW4.

Figure 7. Watercourse running onto shore. Associated with waypoints 10 & 11. Location of freshwater sample LEFW5.

7. SEPA Discharge Consents

Consent Number	Discharge Location	Discharge name	Discharge Type	Discharging to	PE
CAR/L/1002990	NG 65200 15800	MCFF, Loch Eishort	Fish Farm Marine Cage	-	-
CAR/R/1010096	NG 67280 15521	Dwelling Drumfearn, Sleat, Skye	Sewage (Private) Primary	LS	5
CAR/R/1020295	NG 61679 13474	Dwelling, Ord, Sleat, Isle of Skye	Sewage (Private) Primary	LS	6
CAR/R/1021878	NG 60583 11819	Dwelling, Isle of Skye	Sewage (Private) Primary	LS	5
CAR/R/1032562	NG 61640 13370	Dwelling, Ord, Skye	Sewage (Private) Primary	LS	10
CAR/R/1034330	NG 65002 17729	Dwelling, Broadford, Isle of Skye	Sewage (Private) Primary	FW	10
CAR/R/1037572	NG 68789 16050	Dwelling, Drumfearn, Isle Ornsay	Sewage (Public) Secondary	FW	6
CAR/R/1044247	NG 61730 13270	Dwelling, Ord, Isle of Skye	Sewage (Private) Untreated	LS	5
CAR/R/1044444	NG 61660 13430	Dwelling, Ord, Skye	Sewage (Private) Primary	SW	5
CAR/R/1045317	NG 64740 17610	Dwelling, Heaste, Broadford, Isle of Skye	Sewage (Private) Primary	LS	6
CAR/R/1048717	NG 67064 16143	Dwelling, Isle of Ornsay, Isle of Skye	Sewage (Private) Primary	SW	5
CAR/R/1048888	NG 64770 17075	Dwelling, Heaste, Broadford, Isle of Skye	Sewage (Private) Primary	LS	5
CAR/R/1050510	NG 61810 13160	Dwelling, Ord, Isle of Skye IV44 8RN	Sewage (Private) Primary	LS	6
CAR/R/1055490	NG 61801 13399	Dwelling, Ord, Teangue, Isle of Skye	Sewage (Private) Primary	LS	6
CAR/R/1055705	NG 67420 15611	Dwelling, Drumfearn, Isle of Skye	Sewage (Private) Primary	LS	5
CAR/R/1055913	NG 64905 17694	Dwelling, Broadford, Isle of Skye	Sewage (Private) Primary	LS	5
CAR/R/1055929	NG 61712 13170	Dwelling, Ord Sleat, Isle of Skye	Sewage (Private) Primary	LS	5
CAR/R/1056016	NG 64860 17650	Dwelling, Broadford, Isle of Skye	Sewage (Private) Primary	LS	5
CAR/R/1056716	NG 61732 13259	Dwelling, Tigh A'chiobair, Isle of Skye	Sewage (Private) Primary	LS	5
CAR/R/1068218	NG 61839 13173	Dwelling, Ord, Teangue, Sleat, Isle of Skye	Sewage (Private) Primary	LS	5
CAR/R/1070099	NG 64800 17330	Dwelling, Broadford, Isle Of Skye	Sewage (Private) Primary	LS	8
CAR/R/1074466	NG 61686 13373	Dwelling, Ord, Teangue, Isle Of Skye	Sewage (Private) Primary	LS	5
CAR/R/1076168	NG 61750 13400	Dwelling, Ord, Teangue, Isle of Skye	Sewage (Private) Primary	LS	7
CAR/R/1076975	NG 61890 13140	Dwelling, Ord, Isle Of Skye	Sewage (Private) Primary	LS	5
CAR/R/1077014	NG 61880 13140	Dwelling, Ord Isle Of Skye	Sewage (Private) Primary	LS	6
CAR/R/1078398	NG 64623 16982	Dwelling, Heaste, Broadford, Isle of Skye	Sewage (Private) Primary	LS	10
CAR/R/1078505	NG 60740 12050	Dwelling, Tokavaig, Sleat, Isle of Skye	Sewage (Private) Primary	LS	5
CAR/R/1078768	NG 60240 12060	Dwelling, Tokavaig, Isle of Ornsay	Sewage (Private) Primary	LS	6

Consent Number	Discharge Location	Discharge name	Discharge Type	Discharging to	PE
CAR/R/1078936	NG 64612 16916	Dwelling, Heaste, Skye	Sewage (Private) Primary	LS	5
CAR/R/1079412	NG 68140 16200	Dwelling, Drumfearn, Isle Ornsay, Skye	Sewage (Private) Primary	LS	5
CAR/R/1079470	NG 61790 13383	Dwelling, Ord. Isle of Skye	Sewage (Private) Tertiary	LS	6
CAR/R/1079731	NG 61868 13148	Dwelling, Ord,Isle of Skye	Sewage (Private) Primary	LS	5
CAR/R/1079742	NG 61702 13221	Dwelling, Ord Sleat, Isle of Skye	Sewage (Private) Primary	LS	5
CAR/R/1085702	NG 64730 17460	Dwelling, Broadford, Isle of Skye	Sewage (Private) Primary	LS	5
CAR/R/1093199	NG 67900 15730	Dwelling, Drumfearn, Isle of Skye	Sewage (Private) Primary	LS	5
CAR/R/1093587	NG 61820 13686	Dwelling, Ord, Sleat, Isle of Skye	Sewage (Private) Primary	SW	50
CAR/R/1098321	NG 67920 16020	Dwelling, Drumfearn, Isle of Skye	Sewage (Private) Secondary	LS	5
CAR/R/1098323	NG 68010 15960	Dwelling, Drumfearn, Isle of Skye	Sewage (Private) Secondary	LS	5
CAR/R/1107324	NG 67850 15840	Dwelling, Drumfean, Isle of Skye	Sewage (Private) Secondary	FW	5
CAR/R/1111122	NG 61702 13074	Dwelling, Ord, Isle of Skye	Sewage (Private) Tertiary	FW	6
CAR/R/1111988	NG 61800 13430	Dwelling, Ord, Teangue	Sewage (Private) Primary	LS	5
CAR/R/1024994	NG 59540 11490	Dwelling	Sewage (Private) Primary	LS	5
CAR/R/1076488	NG 60164 11776	Dwelling	Sewage (Private) Primary	LS	5
CAR/R/1092097	NG 60340 11660	2 Dwellings	Sewage (Private) Secondary	SW	8

LS=Land/Soakaway, SW= Seawater Body, FW= Freshwater Body, PE= Population Equivalent, - = Not applicable

8. Loch Eishort CTD data

Data obtained during the shoreline survey. The locations of the casts are shown in Figure A8.1.

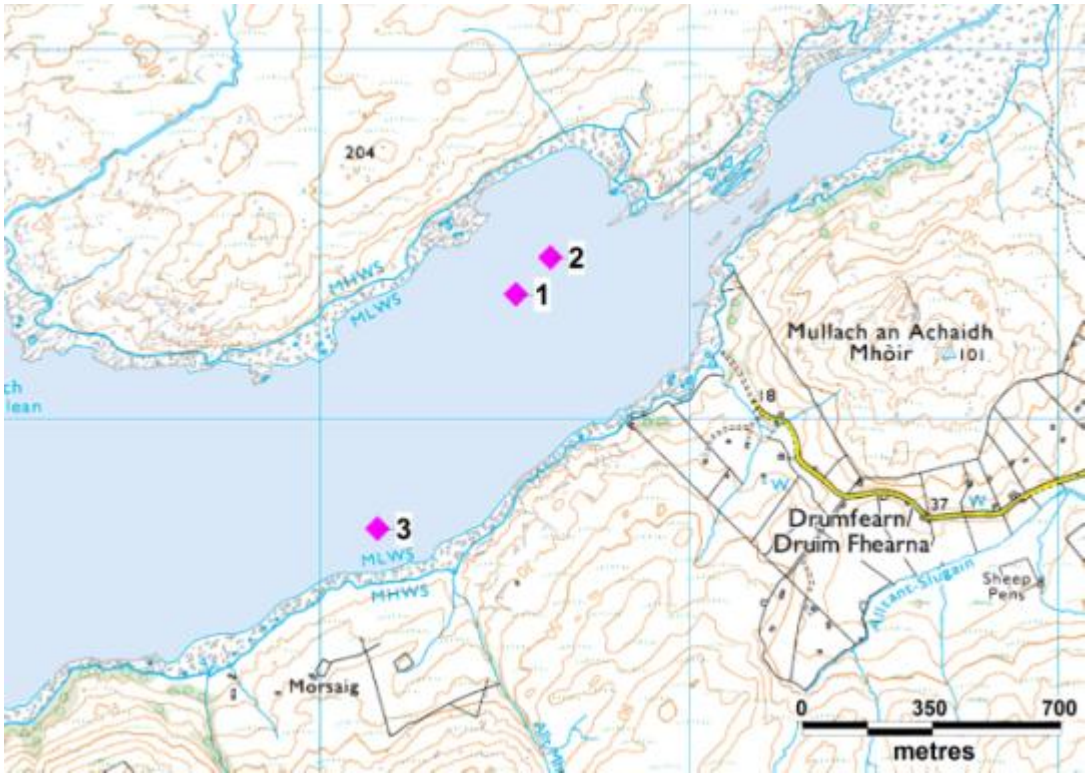

Figure A8.1 Location of CTD cast

CAST 1

Data Header

% Device	10G100653
% File name	10G100653_20140428_110709
% Cast time (local)	28/04/2014 12:07
% Sample type	Cast
% Cast data	Down & up
% Location source	GPS
% Start latitude	57.1782163
% Start longitude	-5.8644319
% Start GPS horizontal error(Meter)	4.409999847
% Start GPS vertical error(Meter)	8.43999958
% Start GPS number of satellites	5
% Cast duration (Seconds)	69.8
% Samples per second	5
Calibration Date	March 2013
Calibration offset for Temperature	-0.033
Calibration offset for Salinity	0.029

CTD data (calibration offsets applied)

Depth (Meter)	Temperature (Celsius)	Salinity (Practical Salinity Scale)
0.14902037	9.907727074	32.98151845
0.447020666	9.707049273	33.14373485
0.745002966	9.650404745	33.13257822
1.042985595	9.637434349	33.12321185
1.340966002	9.623021104	33.14343585
1.638943657	9.609676618	33.13865029
1.936920099	9.59756664	33.14579981
2.234895722	9.584066248	33.13752752
2.53287338	9.572551984	33.11965347
2.830852201	9.52472476	33.11191248
3.128825922	9.481373269	33.14261865
3.426791853	9.465036852	33.16513517
3.724751821	9.444410199	33.18449487
3.922662962	9.449917432	33.16642793
3.922468615	9.421426979	33.20178738
3.724561207	9.39246952	33.1819916
3.42660615	9.390499177	33.18473341
3.128651359	9.392954623	33.18743041
2.830694963	9.428059799	33.18134627
2.532736772	9.48206906	33.1930558
2.234776303	9.540801682	33.18769207
1.936812441	9.557375918	33.18182715
1.638844589	9.580557119	33.16382721
1.340872904	9.593000722	33.15849074
1.042899991	9.600877226	33.16024552
0.744926473	9.605511124	33.15877077
0.446951655	9.607497946	33.15316822
0.148987585	9.610636317	33.20772647

CAST 2

Data Header

% Device	10G100653
% File name	10G100653_20140428_114616
% Cast time (local)	28/04/2014 12:46
% Sample type	Cast
% Cast data	Down & up
% Location source	GPS
% Start latitude	57.1791541
% Start longitude	-5.8630028
% Start GPS horizontal error(Meter)	4.050000191
% Start GPS vertical error(Meter)	5.5
% Start GPS number of satellites	7
% Cast duration (Seconds)	50
% Samples per second	5
Calibration Date	March 2013
Calibration offset for Temperature	-0.033
Calibration offset for Salinity	0.029

CTD data (calibration offsets applied)

Depth (Meter)	Temperature (Celsius)	Salinity (Practical Salinity Scale)
0.149454084	11.75674056	29.56576497
0.447976452	10.47649563	32.52918316
0.746062084	10.0281274	33.08126619
1.044053469	9.881468747	33.22873672
1.342018317	9.834887907	33.27096326
1.639971047	9.809220789	33.31721996
1.937915567	9.790613878	33.33094039
2.235857036	9.79238534	33.3375628
2.533796342	9.783172816	33.34544326
2.915476691	9.770349176	33.39755956
2.914162601	9.692027388	33.35940625
2.532481024	9.672369546	33.33513464
2.234545705	9.681881934	33.33619806
1.936609036	9.709264908	33.33401455
1.638670616	9.702617808	33.3281261
1.34073175	9.703995429	33.33195557
1.042792576	9.710707104	33.33012188
0.744852371	9.726610126	33.3306213
0.446911199	9.726502974	33.32792736
0.148975885	9.723562011	33.33458883

CAST 3

Data Header

% Device	10G100653
% File name	10G100653_20140428_120518
% Cast time (local)	28/04/2014 13:05
% Sample type	Cast
% Cast data	Down & up
% Location source	GPS
% Start latitude	57.1723458
% Start longitude	-5.8700372
% Start GPS horizontal error(Meter)	71.61000061
% Start GPS vertical error(Meter)	12.39000034
% Start GPS number of satellites	15.78999996
% Cast duration (Seconds)	45.4
% Samples per second	5
Calibration Date	March 2013
Calibration offset for Temperature	-0.033
Calibration offset for Salinity	0.029

CTD data (calibration offsets applied)

Depth (Meter)	Temperature (Celsius)	Salinity (Practical Salinity Scale)
0.149141174	11.30933665	32.23108791
0.447259116	10.11977244	33.23735889
0.745229877	10.01052496	33.29750013
1.043189878	9.987353207	33.30072143
1.34114764	9.969297341	33.3054007
1.639100294	9.944549091	33.33359942
1.937048623	9.939344578	33.33413495
2.234989218	9.894180827	33.38803108
2.532930468	9.888721233	33.31453315
2.830878185	9.836695393	33.31575256
3.128821273	9.804004052	33.33430065
3.285853779	9.792208664	33.36872163
3.285393482	9.755695335	33.36564759
3.128363641	9.754395209	33.36368204
2.830432044	9.771417006	33.36328911
2.532498963	9.782262287	33.35949364
2.234563632	9.793449106	33.35112412
1.936626234	9.812327855	33.35064747
1.638686617	9.838230998	33.34406779
1.340744705	9.854767429	33.34243719
1.042801655	9.835248095	33.33638736
0.744859537	9.834861015	33.3494035
0.446917507	9.86530919	33.34656442
0.148979654	9.87586117	33.33894731