Scottish Sanitary Survey Report

Sanitary Survey Report
Loch Slapin
SL-194-290-08
September 2014

Cefas

Food Standards Agency
food.gov.uk
Buidheann Inbhe-Bidhe

Report Title	Loch Slapin
Project Name	Scottish Sanitary Survey
Client/Customer	Food Standards Agency Scotland
Cefas Project Reference	C6316A
Document Number	C6316A_2014_03
Revision	V1.0
Date	12/09/2014

Revision History

Revision number	Date	Pages revised	Reason for revision
0.1	29/07/2014	All	Draft report for review
1.0	12/09/2014	12, 41	Correction of typographical errors

	Name	Position	Date
Author	Jessica Larkham, Frank Cox, Liefy Hendrikz, Ron Lee	Scottish Sanitary Survey Team	12/09/2014
Checked	Michelle Price-Hayward	Senior Shellfish Hygiene Scientist	12/09/2014
Approved	Michelle Price-Hayward	Senior Shellfish Hygiene Scientist	12/09/2014

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 Slapin

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
	Duncan Henderson	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 Slapin 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/eu-good-practice-guide.aspx). This area 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 Slapin is a sea loch on the west coast of Skye, an island off the west coast of Scotland. The loch is bounded to the west by the Strathaird peninsula, and to east by a series of peaks extending southward from Beinn Dearg Bheag that separate Loch Slapin from Loch Eishort.

The fishery at Loch Slapin is comprised of a single, long-line mussel (*Mytilus edulis*) farm located within 150 m of the western shoreline, approximately 4 km south of the loch head.

The principal sources of contamination lie on the northeast shore of the loch, around Torrin, and on the southwest shore around Kirkibost. Those around the Torrin area constitute the largest potential inputs from both human and diffuse sources. The available information indicates that the transport distance may be greater in a southerly direction than a northerly one, although this will not be the case during strong north winds. Overall, it is likely that the sources around the Torrin area will have a greater impact on water quality at the fishery than those around the Kirkibost area.

It is recommended that the production area be curtailed at its northern boundary to exclude areas nearer identified sources around the head of the loch, and that the RMP be moved to the northern end of the mussel farm to reflect the contamination being transported southwards from the area around Torrin. 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 Slapin
Site Name	Cruaidhlinn
SIN	SL-194-290-08
Species	Common mussels
Type of Fishery	Longline aquaculture
NGR of RMP	NG 5694 1828
East	156940
North	818280
Tolerance (m)	40
Depth (m)	1-3
Method of Sampling	Hand
Frequency of Sampling	Monthly
Local Authority	The Highland Council: Skye and Lochalsh
Authorised Sampler(s)	Allan MacDonald
Local Authority Liaison Officer	Alan Yates
Production Area Boundaries	The area within lines drawn between NG 5613 1700 to NG 5875 1700 and between NG 5690 1900 and NG 5831 1900 and extending to MHWS

III. Report

1. General Description

Loch Slapin is a sea loch on the west coast of Skye, an island off the west coast of Scotland and is part of the Skye and Lochalsh district of the Highland Council. The loch is bounded to the west by the Strathaird peninsula, and to east by a series of peaks extending southward from Beinn Dearg Bheag that separate Loch Slapin from Loch Eishort. Loch Slapin has a southerly aspect. The conjunction of Loch Slapin and Loch Eishort opens to Cuillin Sound.

The area around Loch Slapin is sparsely inhabited with the main population located in the village of Torrin, at the head of the loch.

Loch Slapin is 6.9 in length. It has a maximum width of 3 km, average depth of 6.1 m and a maximum recorded depth of 35 m (Edwards & Sharples, 1986).

A sanitary survey was undertaken on the classified fishery at Loch Slapin Loch Slapinon 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/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.

Further details of the recommendations can be found in the Sampling Plan and in Section 17 of this report.

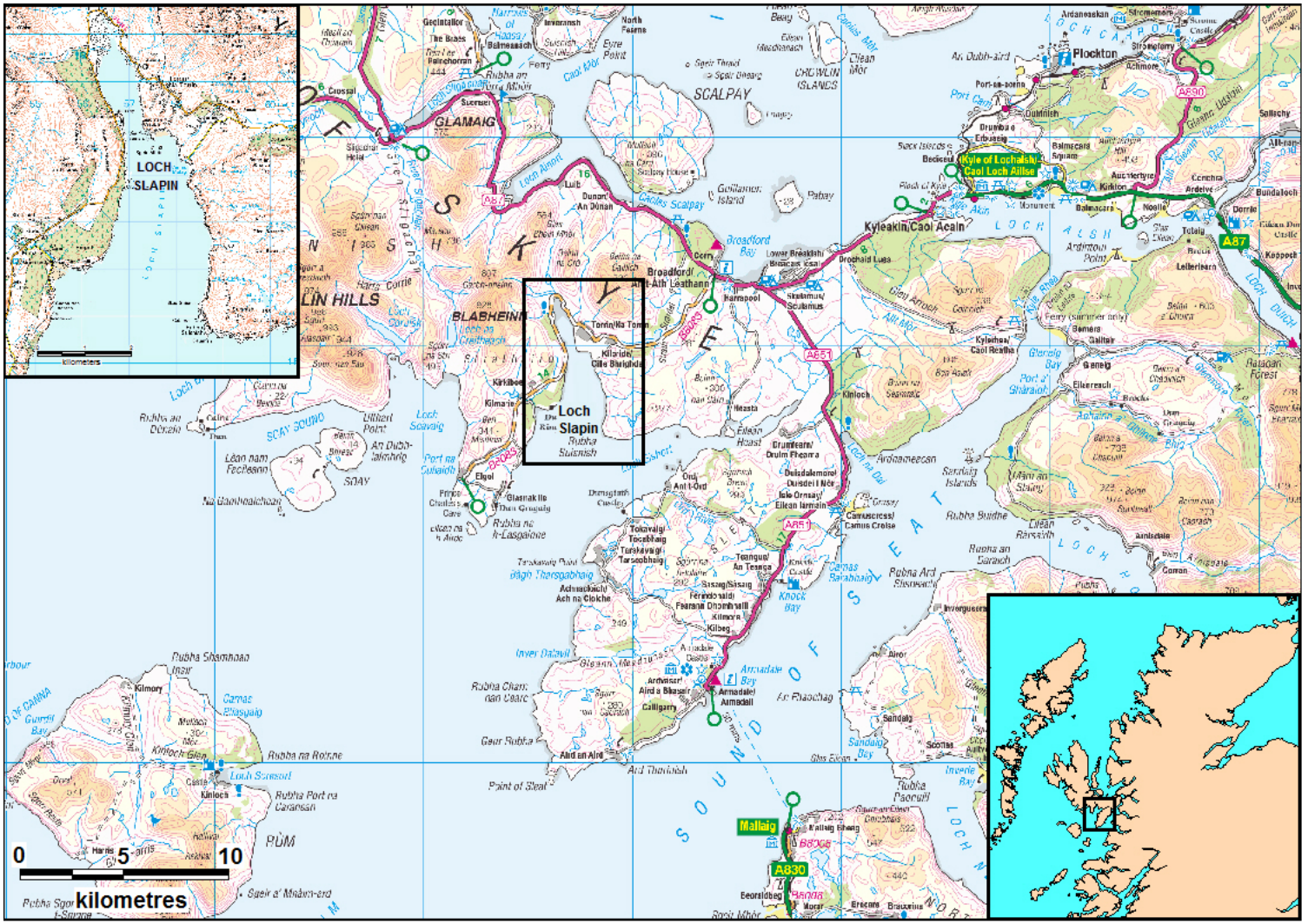


Figure 1.1 Location of Loch Slapin

2. Fishery

The fishery at Loch Slapin is comprised of a single common mussel (*Mytilus edulis*) farm which has been classified for production since 2005. Details of the classified site are presented in Table 2.1.

Table 2.1 Area shellfish farms – Loch Slapin

Production area	Site	SIN	Species	RMP
Loch Slapin	Cruaidhlinn	SL-194-290-08	Common mussels	NG 5689 1811

The production area boundaries are defined as the area within lines drawn between NG 5613 1700 to NG 5875 1700 extending to MHWS. At the time of the shoreline survey, six long lines were present. These were 200 m in length with 6 m droppers. Two of the lines were undergoing maintenance at the time. Little stock was present and this was attributed to a lack of natural spat settlement over the previous three years. Harvesting was stated to occur year round when possible. The RMP lies at the southern end of the mussel lines.

The fishery location described in the shoreline survey report is plotted in Figure 2.1

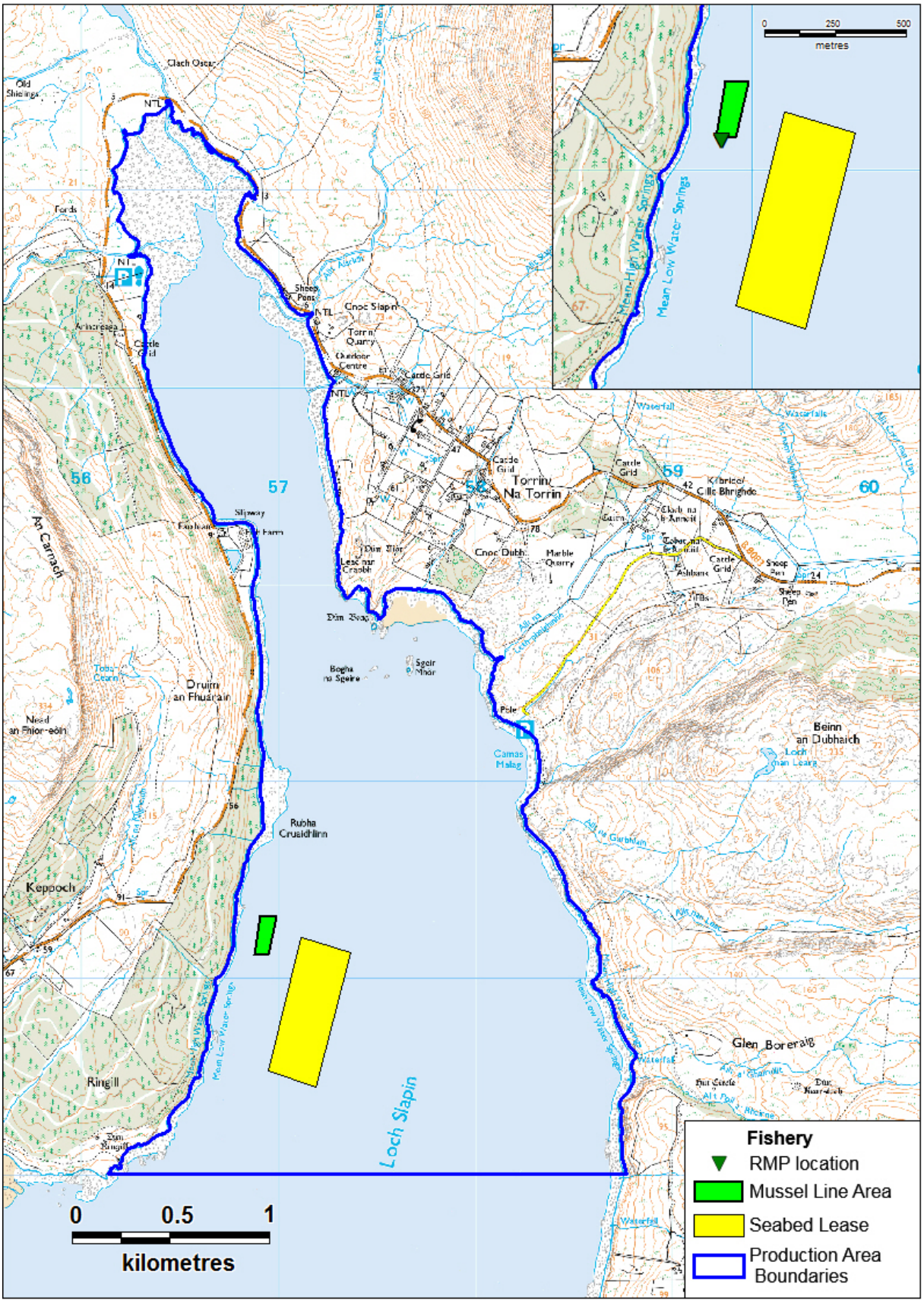


Figure 2.1 Loch Slapin Fishery

3. Human Population

Information was obtained from the General Register Office for Scotland on the population within the vicinity of Loch Slapin production area. The last census was undertaken in 2011. The recorded population per census output area is shown in Table 3.1. The census output areas surrounding Loch Slapin are shown thematically mapped by the 2011 population densities in Figure 3.1. Overall, the population density is low (< 3 people per km^2) along the majority of the shoreline surrounding the loch. The majority of the population in census output area S00081103, which has the highest density, is located on the opposite side of the Strathaird peninsula to Loch Slapin.

Table 3.1 Census output areas and populations – Loch Slapin

Census Output Area	Population
S00081090	124
S00081094	149
S00081103	135

The B8083 links the village of Torrin on the northeast shore with smaller settlements around the southwest shore, where there are scattered dwellings around Kirkibost and on to Elgol, on the west side of the Strathaird peninsula. Torrin has a council-run outdoor education centre and holiday accommodation, including at least 12 self catering cottages and B&Bs (blaven.com, n.d.). During the shoreline survey, a caravan was observed parked at the end of the road leading to the car park at Camas Malag. The shoreline is generally accessible by road or track apart from the southwestern shoreline of the loch where the B8083 diverts inland. There are a few dwellings on the west side of the loch, to the northwest of the observed mooring.

There is a single anchorage located at the northern end of the loch adjacent to the slipway (Admiralty Chart 2208. During the shoreline survey, a mooring buoy was observed south east of Kirkibost, a boat was observed on land next to the slipway on the western shoreline and 4 boats were observed at the northern end of the loch.

Torrin is the principal centre of population around the loch. As it contains a relatively large amount of holiday accommodation, any faecal contamination arising from that community is likely to have a sizeable seasonal variation. The area in general is used by climbers and hill walkers attempting the Cuillin range, and therefore the tourist season may be expected to extend beyond the traditional summer holiday months.

There may be localised episodes of pollution arising from any boats that discharge septic waste directly to loch. Overall, potential impacts to the water quality from human sources at the shellfish farm are likely to be low.

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

4. Sewage Discharges

Data relating to sewage discharges within an area 7.5 km around the point NG 5690 1810 (the vicinity of the shellfish farm) was sought from Scottish Water and the Scottish Environment Protection Agency (SEPA). Data requested included the name, location, type, size (in either flow or population equivalent), level of treatment, sanitary or bacteriological data, spill frequency, discharge destination (to land, watercourse or sea), any available dispersion or dilution modelling studies, and whether improvements were in work or planned. Summary information only was supplied by both organisations.

4.1 Community Discharges

Scottish Water and SEPA did not report any community discharges located within the area covered by the request.

4.2 Consented Private Discharges - SEPA

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

Registration of septic tanks 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 provision of the data, however there may be additional discharges that were not yet registered with SEPA, or have been installed since that date.

SEPA provided information on 78 sewage discharge consents around Loch Slapin. These discharges were primarily around the village of Torrin, which is on the eastern shore near the head of Loch Slapin. Other discharges are located along the western shore of Loch Slapin and on the southern shore of Loch Eishort.

The majority of the 78 consents reported discharge to soakaway. The effectiveness of soakaway systems depends on location and maintenance, and SEPA have identified previously that in remote areas, consents originally registered as discharging to land may be diverted to sea or watercourses upon failure of the soakaway fields.

A summary of the information provided on consented discharges by SEPA is given in Appendix 7. The locations of the discharges are shown in Figure 4.1. Two of the discharges with the largest population equivalent (PE) values were given as entering the Abhainn Cille Mhaire, located at Kirkibost to the southwest of the fishery.

SEPA provided information for two water treatment work consents. Backwash effluent from filter cleaning can concentrate pollutants and may have significant *E. coli* loadings.

Information was also provided on a consented discharge from a quarry, which may introduce chemical pollutants to the surrounding areas.

Shoreline Survey Discharge Observations

No observations of sewage or sewage 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. Many discharges are located around the village of Torrin but the majority of these are to land.

The nearest discharges to the fishery are two septic tanks at Kirkibost discharging to Abhainn Cille Mhaire, which flows into the loch less than 2 km from the mussel lines.

Discharges from septic tanks at the mouth of Loch Eishort may also have an impact on the fishery.

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

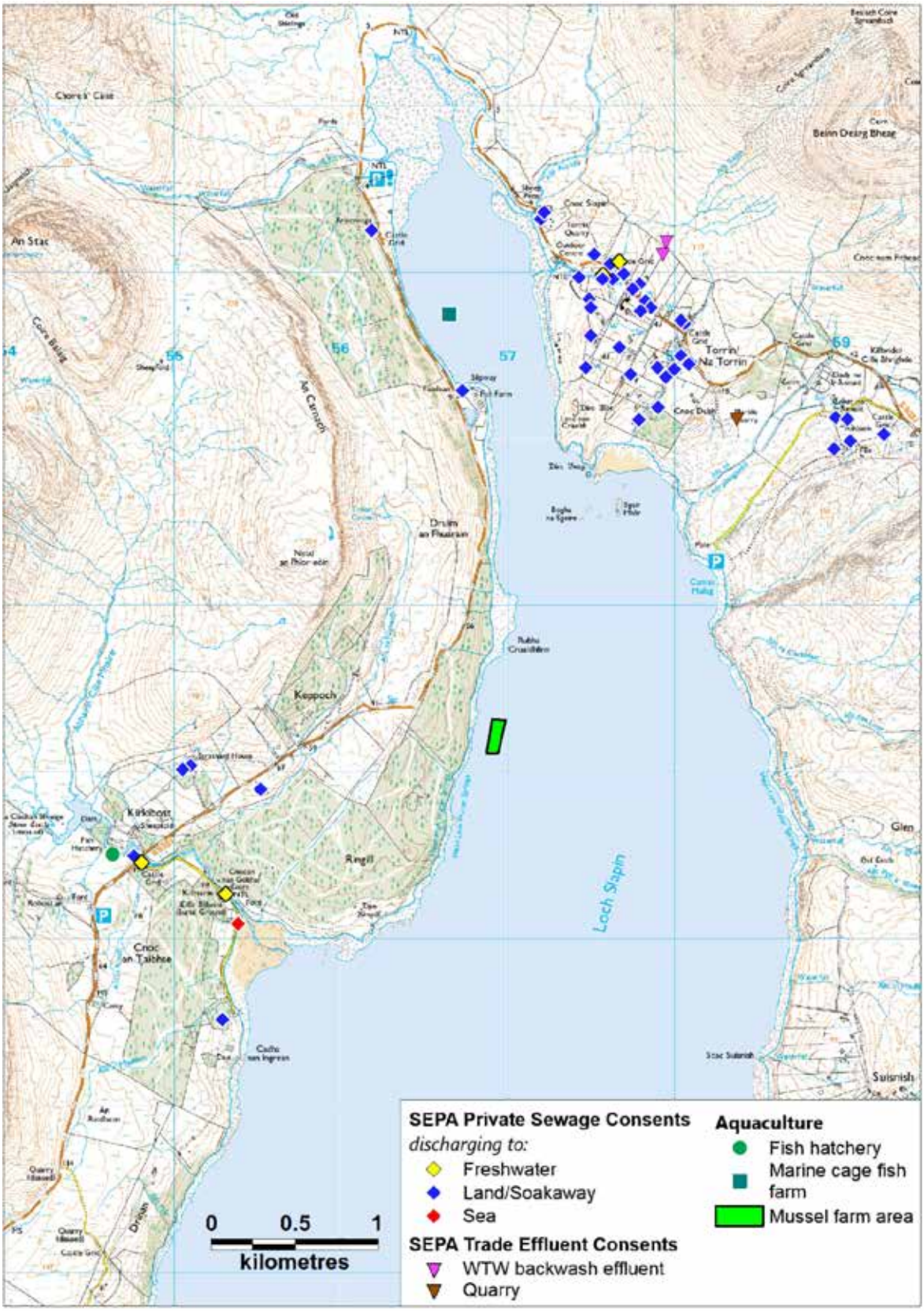


Figure 4.1 Map of discharges for Loch Slapin

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 area. Agricultural census data to parish level was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for the Strath parish. Reported livestock populations for the parish 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 fewer 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 agricultural parish 2013

	Strath	
	280 km^2	
	Holdings	Numbers
Pigs	*	*
Poultry	22	205
Cattle	31	522
Sheep	40	6,919
Other horses and ponies	10	20

* data withheld

The livestock census numbers for Strath relate to a very large parish area, therefore it is not possible to determine the spatial distribution of the livestock on the shorelines adjacent to the loch or identify how many animals are likely to impact the catchment around the fishery. Therefore the figures are of little use in assessing the potential impact of livestock contamination to the fishery; however they do give an idea of the total numbers of livestock over the broader area. Sheep predominated with cattle also present in moderate numbers. There were small numbers of horses and ponies and fewer than five holdings of pigs.

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 29th 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, sheep often with lambs were observed grazing along much of the northern and eastern shoreline of the loch. No livestock were observed on the western shoreline directly adjacent to the mussel farm.

Review of publicly available aerial images shows that areas of improved pasture are located inland south east of the mussel farm and also inland and along the eastern

coastline of the loch (Bing Maps, accessed 25/06/2014). Areas identified from the aerial images as likely improved pasture are shown in Figure 5.1. Sheep dips were identified by SEPA on the eastern coastline of the loch. Ordnance Survey identified several cattle grids and sheep pens on the eastern coastline around the Torrin area and also a cattle grid and sheepfold, inland south west of the mussel farm close to Kirkibost.

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 were observed on the on the north east coastline of the loch, however the presence of the cattle grid and sheepfold inland south west of the shellfish farm, suggests livestock could be present in this area. However, the available information suggests that the predominant potential impact from farm animal sources lies towards the head of the loch.

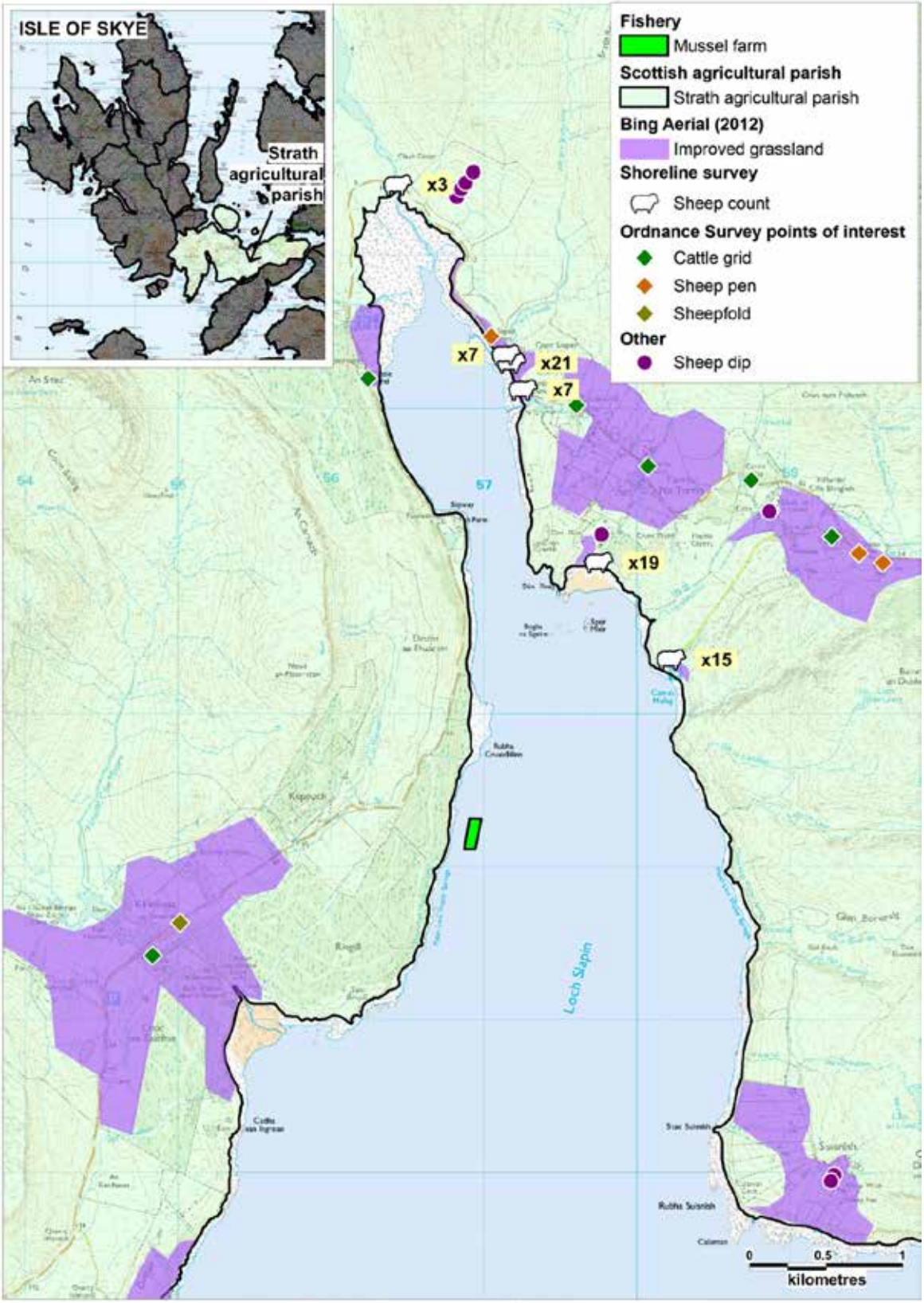


Figure 5.1 Livestock observations at Loch Slapin

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 Slapin 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 Slapin with similar numbers recorded at nearby Loch Eishort. There are also anecdotal accounts of seals around the coastline (Unique Cottages, n.d.). No seals were observed during the shoreline survey.

Cetaceans

There are anecdotal accounts of a relatively large sized pod of 30 common dolphins in Loch Slapin ((Skye Birds, 2014). However, no sightings have been reported by the Hebridean Whale and Dolphin Trust. 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.). No cetaceans were observed during the shoreline survey.

Birds

Seabird data was downloaded from the collated JNCC dataset from the website (JNCC, 2014) in March 2014. The dataset was then manipulated to extract 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). No seabird data was available for an area within 5 km of the fishery. However, in 2002 significant numbers of Arctic terns, common terns and herring gulls were observed approximately 8 km to the southeast of Loch Slapin.

There are also reports of a variety of other birds in the area (Skye Birds, 2014), with species including turnstone, black-throated divers, whimbrels, Canadian geese,

whooper swans, razorbills, great Northern divers, grey wagtails and gooseanders all noted in 2013. The website does not report all sightings, particularly for more common species and therefore may not reflect the most numerous birds in an area.

During the shoreline survey, birds were the only wildlife observed, with gulls, oystercatchers and cormorants being the most common. Some of the birds were noted on the water (mostly gulls), whilst cormorants, gulls and an eider duck were noted on the mussel farm.

Deer

The Isle of Skye is noted to support a significant 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. However there are no available records indicating deer populations are found around Loch Slapin. 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.). A designated conservation area for otters is present in the adjacent Loch Eishort, which is located approximately 10 km to the southeast, though it remains unclear whether the otters would travel to Loch Slapin. No otters were observed during the shoreline survey.

Overall

Wildlife is not anticipated to be a significant contamination impact to the fisheries at Loch Slapin. They are however expected to contribute to background levels of contamination at both fisheries. Contamination from seabirds is expected to be the most significant contribution with the most significant coming from those at the mussel farm. Without further data, the distribution of impact across the mussel farm is assumed to be similar. There may be some impact on background water quality from seals, deer and otters.

Figure 6.1 Map of seabird distributions if relevant.

7. Land Cover

There are no built up or urban areas represented. The Land Cover Map 2007 data for the area is shown in Figure 7.1. The predominant land cover types adjacent to Loch Slapin are dwarf shrub heath, coniferous and broad leaved woodland, improved grassland and rough grassland. There are also scattered small areas of bog and acid grassland. The shoreline west of the mussel lines is composed of coniferous and broadleaved woodland, with dwarf shrub heath and rough grassland inland and an area of improved grassland to the south. There is also a large area of improved grassland on the north eastern shoreline of the loch.

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

The highest potential contribution of contaminated run-off to the Loch Slapin mussel farm is from the areas of improved grassland located inland and adjacent to the fishery and also on the coastline south of the fishery. Any impact is likely to be greatest at the southern end of the mussel farm. This contribution would be expected to increase after rainfall events.

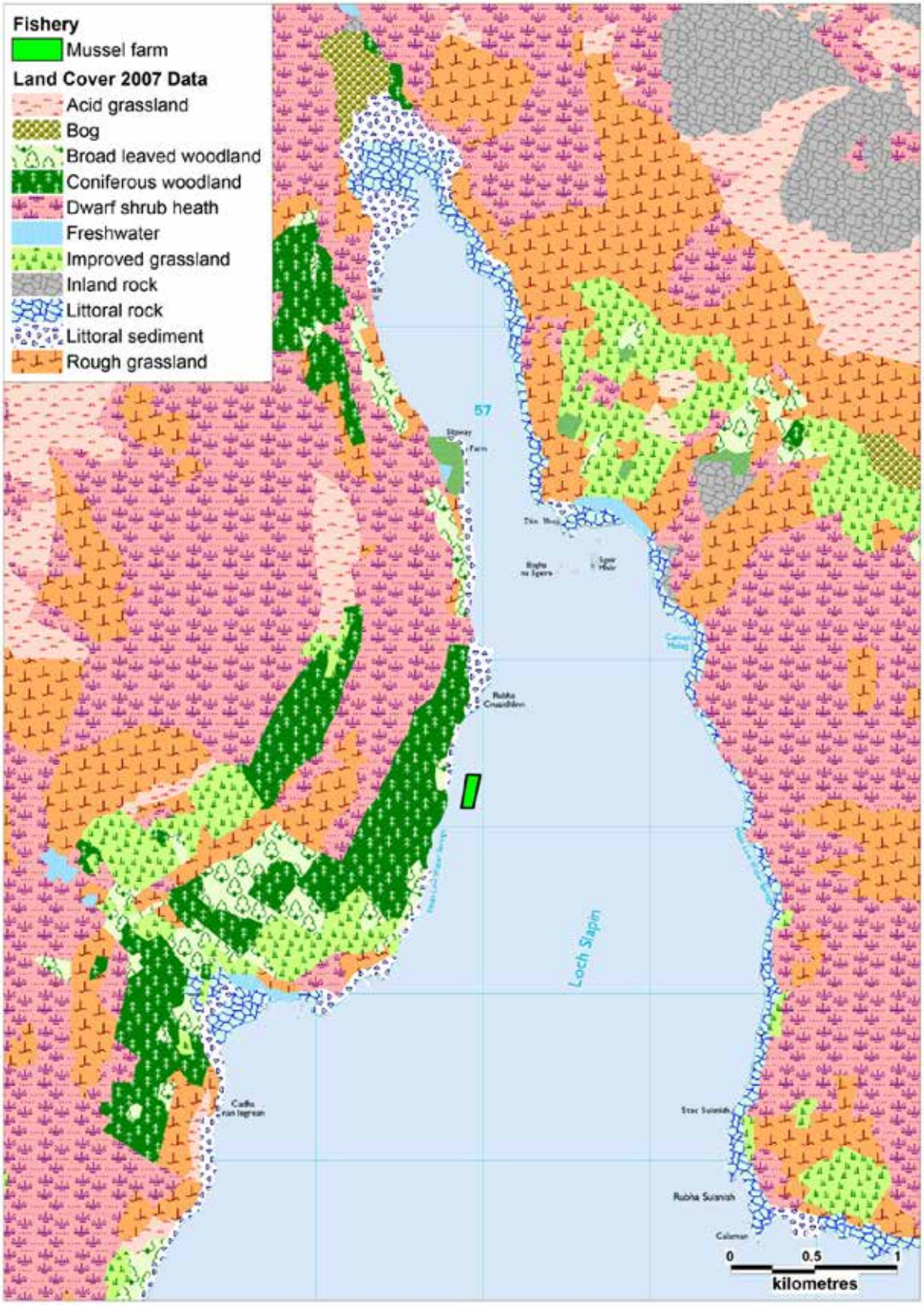


Figure 7.1 LCM2000 class land cover data for Loch Slapin

8. Watercourses

There are no gauging stations on watercourses entering Loch Slapin.

Spot measurements of flow and microbial content were obtained during the shoreline survey conducted on the 18th 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, however a dry stream bed was observed on the western coastline of the loch adjacent to the mussel farm. The locations and loadings of measured watercourses are shown in Figure 8.1.

Table 8.1 Watercourses entering Loch Slapin

No.	Eastings	Northings	Description	Width (m)	Depth (m)	Flow (m^3/d)	Loading (*E. coli* per day)
1	155393	817182	Abhainn Cille Mharie	7.6	0.18*	9010*	9×10^9
2	156130	821685	Allt na Dunaiche	4.2	0.17*	7750*	$< 7.7 \times 10^{8**}$
3	156444	822498	Abhainn an t-Sratha Mhòir	11.3	0.20*	8630*	6.9×10^9
4	157168	821375	Allt Aisridh	4.0	0.35*	22200*	1.3×10^{10}
5	157283	821027	Allt Slapin	5.4	0.17*	16100*	9.5×10^{10}
6	157756	820006	Unnamed watercourse	1.5	0.16	914	9.1×10^{10}
7	158140	819625	Allt na Leth-pheighinne	2.3	0.19	2340	3.3×10^9

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

None of the recorded watercourses flow into the immediate vicinity of the mussel farm. Watercourse numbers 1, 6 and 7 are within 2 km of the mussel farm. All of the watercourses had moderate calculated loadings: the highest estimated loadings were associated with watercourses numbered 4 to 6 located in the vicinity of Torrin to the northeast of the fishery.

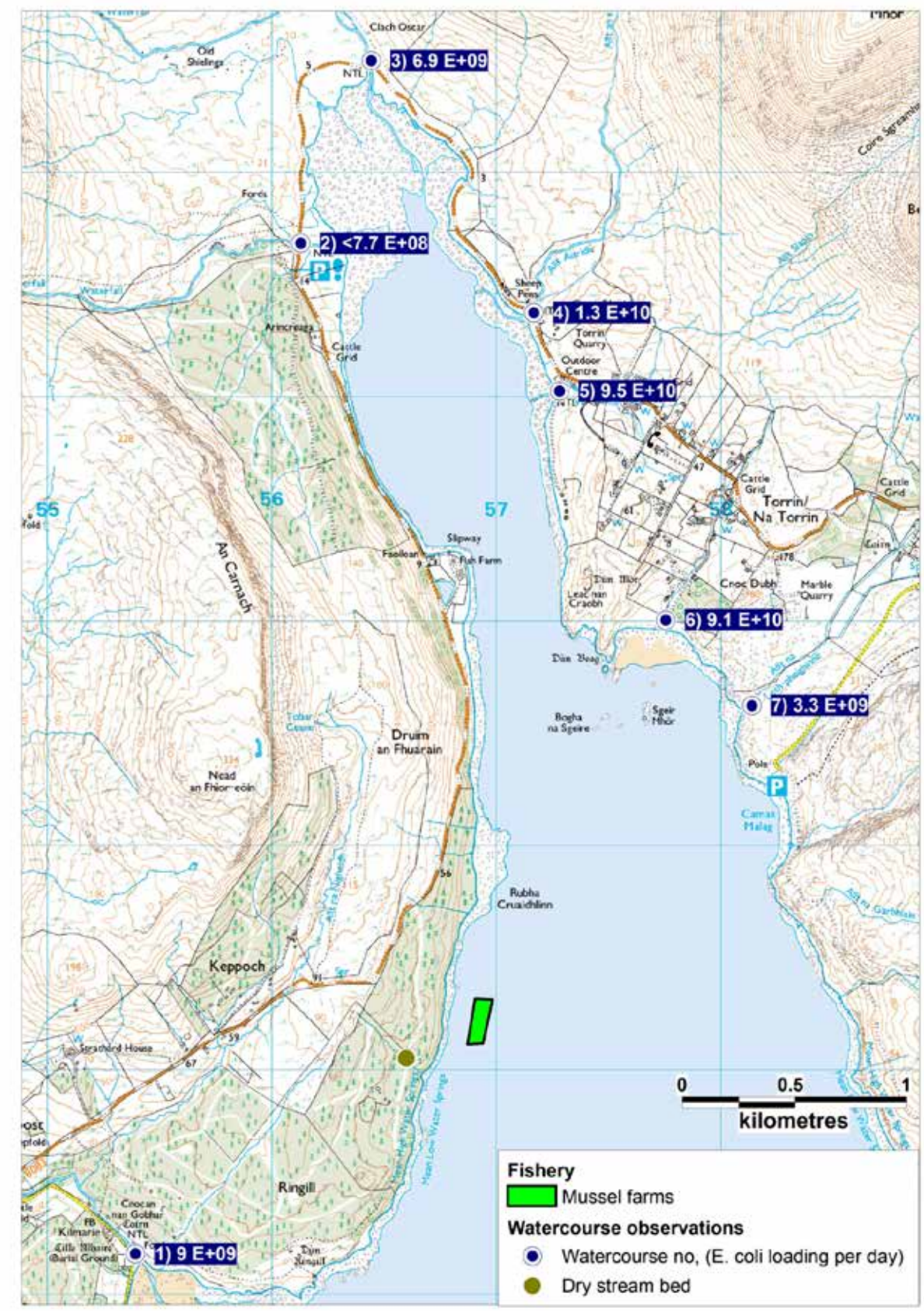


Figure 8.1 Map of watercourse loadings at Loch Slapin.

9. Meteorological Data

The nearest weather station for which a nearly complete rainfall data set was available is Skye: Lusa, situated approximately 16 km to the north east of the production area. Rainfall data was available for January 2008 – December 2013 but data were excluded from assessment during validation when they were made up of accumulated or estimated values. Rainfall data for the following dates was excluded from the analysis: 11/01/08-14/01/08, 31/03/08, 01/04/08, 04/06/08-05/06/08, 16/06/08-19/06/08, 04/05/09-05/05/09, 17/05/09-18/05/09, 10/08/09-11/08/09, 01/12/2010-02/12/2010, 16/08/11-20/08/11, 22/08/11, 29/10/11-30/10/11, 22/08/12-23/08/12 and 04/12/12-05/12/12.

The nearest wind station is situated at South Uist: Range, located 84 km west of the production area. Conditions may differ between this station and Loch Slapin due to the distance 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 *.

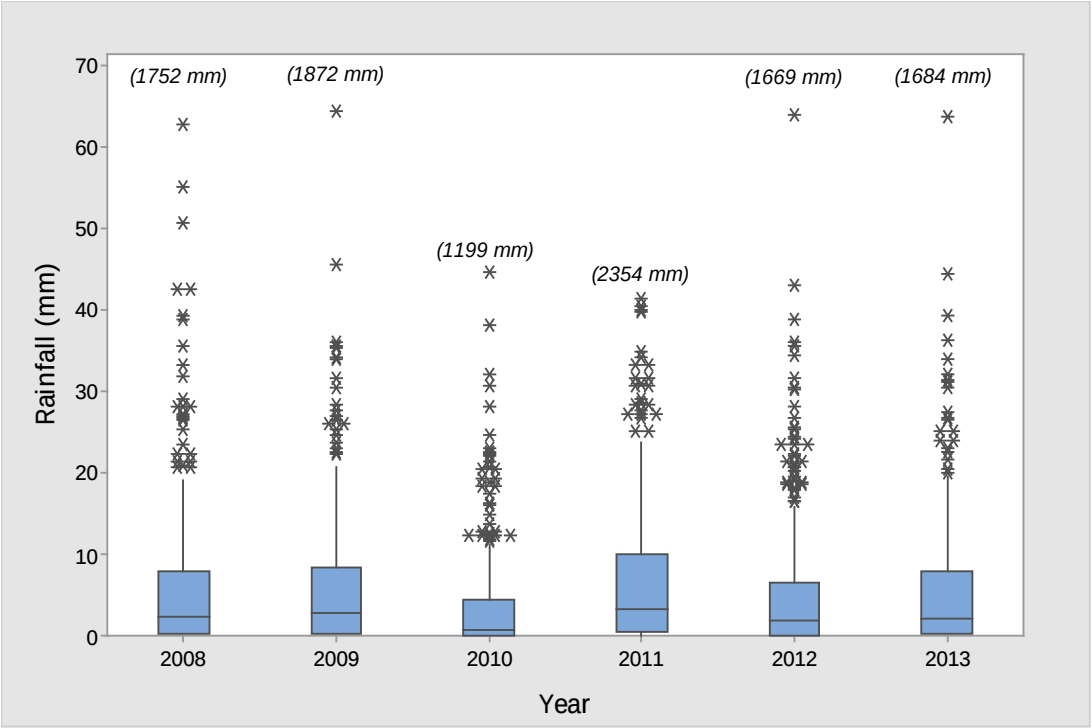


Figure 9.1 Box plot of daily rainfall values by year at Skye: Lusa (2008 – 2013)
(total rainfall values in parentheses)

Daily rainfall values varied from year to year, with 2010 having 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.

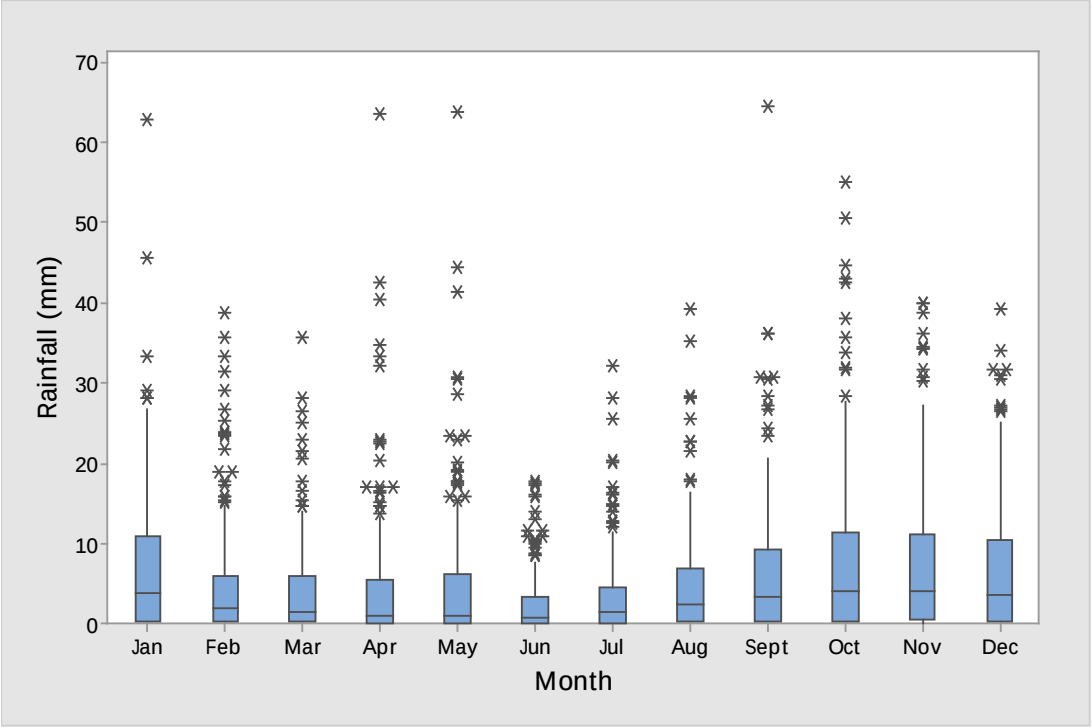


Figure 9.2 Box plot of daily rainfall values by month at Skye: Lusa (2008 – 2013)

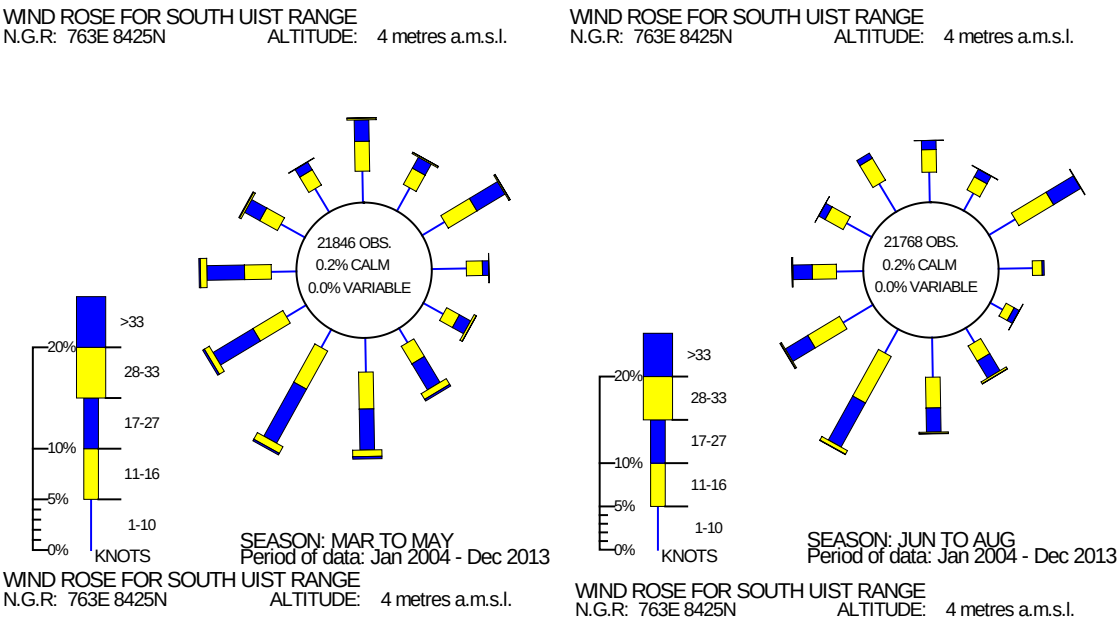
Daily rainfall values were higher during the autumn and winter. Rainfall was greatest in October (1348 mm). Weather was driest in June (429 mm). Rainfall values exceeding 30 mm/d occurred in all months except June and high rainfall values of 60 mm/d were seen in January, April, May and September.

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.



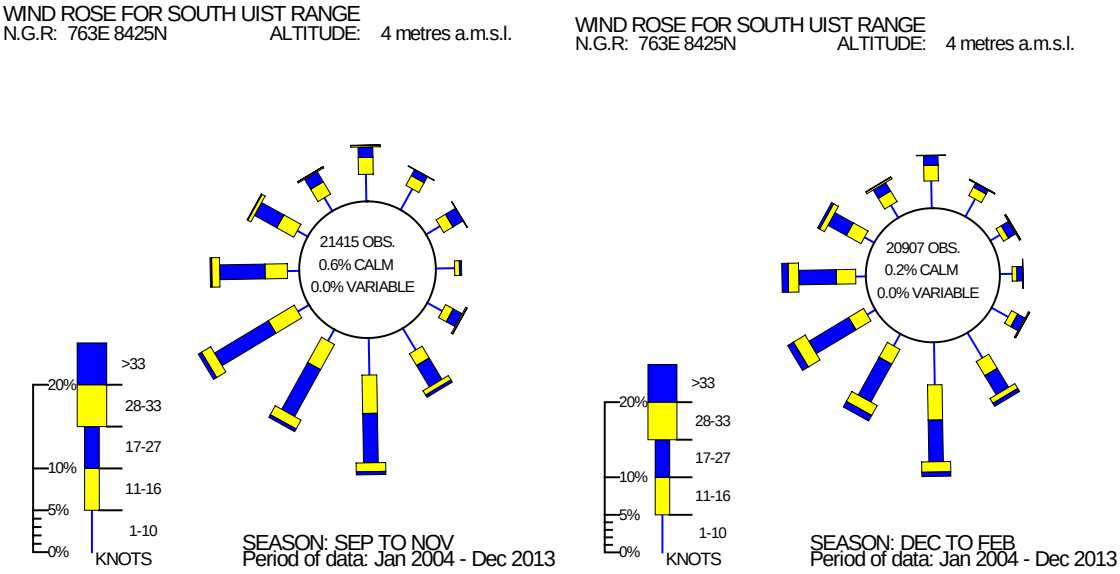


Figure 9.3 Seasonal wind roses for South Uist: Range

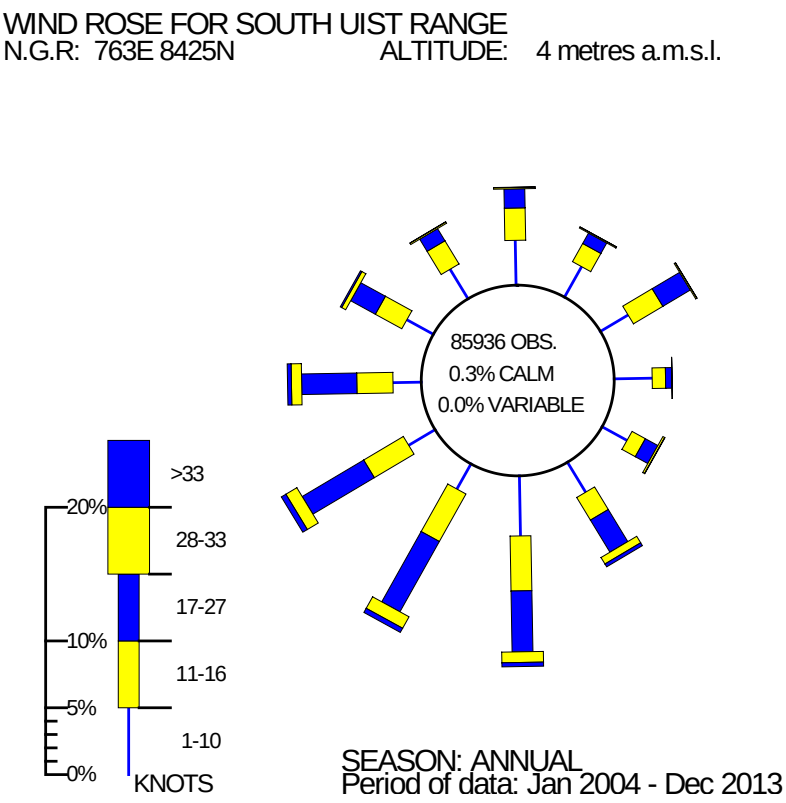


Figure 9.4 Annual wind rose for South Uist: Range

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 came 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 Slapin has been classified forthe production of common mussels (*Mytilus edulis*) since 2005. The classification history since 2006 is listed in Table 10.1 below.

Table 10.1 Loch Slapin: (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	A	A	A	A	A
2008	A	A	A	A	A	A	B	B	B	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 area has been classified as year-round A since 2009.

11. Historical *E. coli* Data

Results for all samples assigned against to the Loch Slapin production area for the period 01/01/2009 to the 16/06/2014 were extracted from the FSAS database on 16/06/2014 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.

One sample did not have a result recorded and was excluded from further analysis. The remaining 64 samples were delivered to the laboratory within 48 hours and had box temperatures of 8^{o}C or less.

A total of 31 results reported as <20 (below the limit of detection) were reassigned a value of 10 *E. coli* MPN/100 g for the purposes of statistical evaluation and graphical representation.

11.1 Summary of microbiological results

Table 11.1 Summary of historical sampling and results

Sampling Summary	
Production area	Loch Slapin
Site	Cruaidhlinn
Species	Common mussels
SIN	SL-194-290-08
Location	Various
Total no of samples	64
No. 2009	12
No. 2010	11
No. 2011	12
No. 2012	12
No. 2013	12
No. 2014	5
Results Summary	
Minimum	<20
Maximum	1700
Median	20
Geometric mean	27
90 percentile	230
95 percentile	715
No. exceeding 230/100g	5 (8%)
No. exceeding 1000/100g	1 (2%)
No. exceeding 4600/100g	0
No. exceeding 18000/100g	0

Sample results at Loch Slapin have been predominantly low between 2009 and 2014, with nearly half of samples returning results below the limit of detection.

11.2 Overall geographical pattern of results

The geographical locations of all samples assigned to Loch Slapin are mapped thematically in Figure 11.1. Thirteen samples had unverified sampling locations: NGRs were given for three of these and these samples were included in Figure 11.1. Thirty-five samples, including the three unverified samples for which a grid reference had been given, were reported as having been taken at the same location, situated approximately 400 m to the southeast of the mussel lines. The last sample for which this location was given was taken in September 2013. Three other samples were reported to have been taken 300 metres to the south of that location. The reported sampling locations for the other verified samples generally lay around the southern end of the present mussel lines although one lay at the northern extent of the mussel lines and two plotted on land nearby. Further geographical analysis was not undertaken due to uncertainty regarding the exact location from which a significant proportion of samples had been taken.

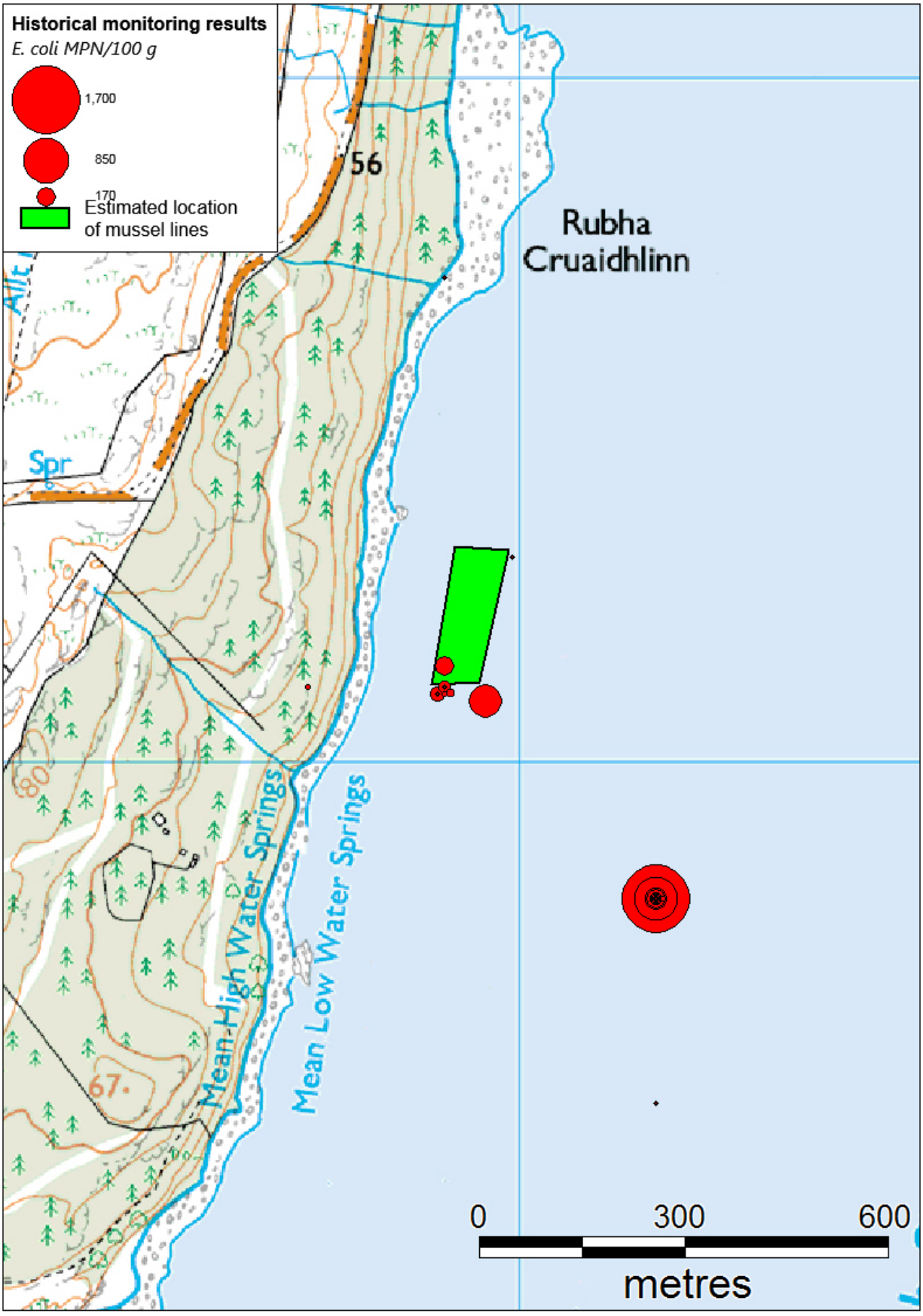


Figure 11.1 Map of reported sampling locations for common mussels at Loch Slapin

11.3 Overall temporal pattern of results

A scatterplot of *E. coli* results against date for Loch Slapin 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.

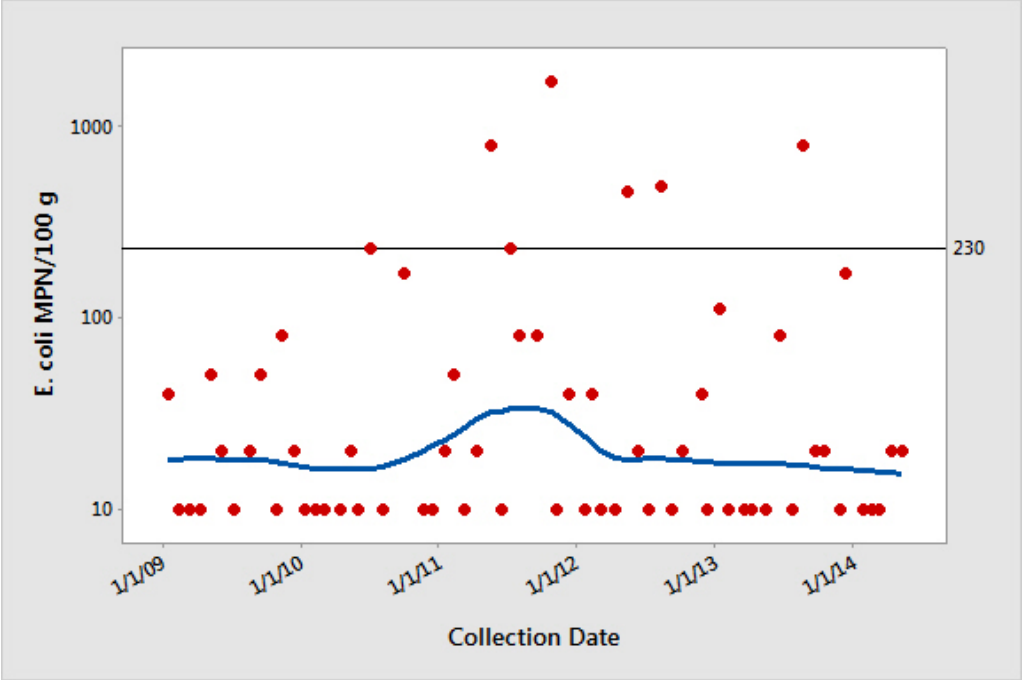


Figure 11.2 Scatterplot of *E. coli* results by collection date at Loch Slapin, fitted with a lowess line

A slight increase in contamination levels is shown between 2011 and 2012, contributed to a lack of results at <20 *E. coli* MPN/100 g coinciding with two of the highest results seen in the area.

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 Slapin is displayed in Figure 11.3. Jittering was applied at 0.02 (x-axis) and 0.001 (y-axis) respectively.

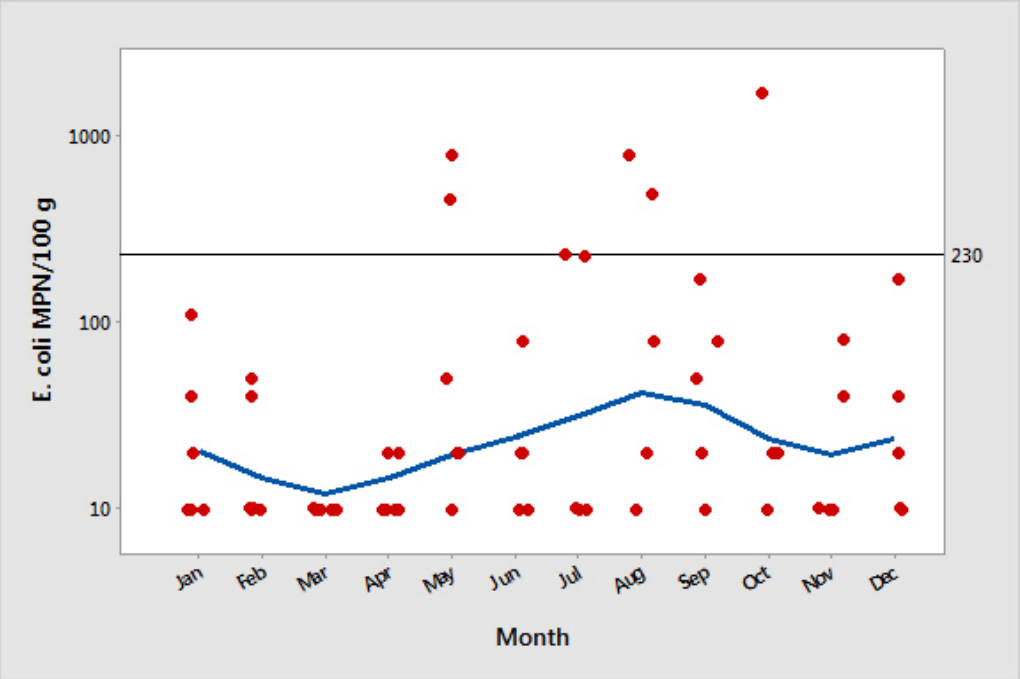


Figure 11.3 Scatterplot of *E. coli* results by month at Loch Slapin, fitted with a lowess line

All results from samples taken in March were less than 20 *E. coli* MPN/100 g. Results exceeding 230 *E. coli* MPN/100 g were from samples taken in May, August and October. The two results of 230 *E. coli* MPN/100 g occurred in July.

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 Slapin is presented in Figure 11.4.

No statistically significant differences were found between *E. coli* results for Loch Slapin by season (one-way ANOVA, p = 0.36) (Appendix 4).

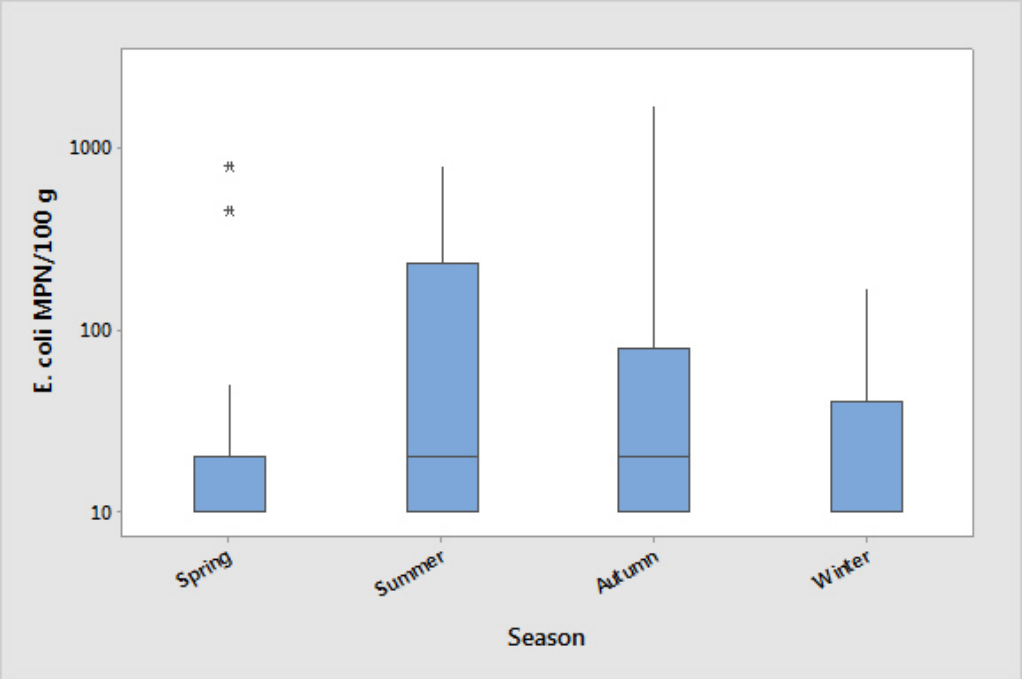


Figure 11.4 Boxplot of *E. coli* results by season at Loch Slapin

11.4.1 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.

11.4.2 Analysis of results by recent rainfall

The nearest weather station with available rainfall data was at Skye: Lusa approximately 16 km northeast of Loch Slapin. Rainfall data was purchased from the Meteorological Office for the period of 01/01/09 - 31/12/2013 (total daily rainfall in mm).

11.4.2.1 Two-day rainfall

A scatterplot of *E. coli* results against total rainfall recorded on the two days prior to sampling for Loch Slapin is displayed in Figure 11.5. Rainfall data was available for 59 of the 64 sampling occasions. Jittering was applied to the symbols at 0.02 (x-axis) and 0.001 (y-axis) respectively.

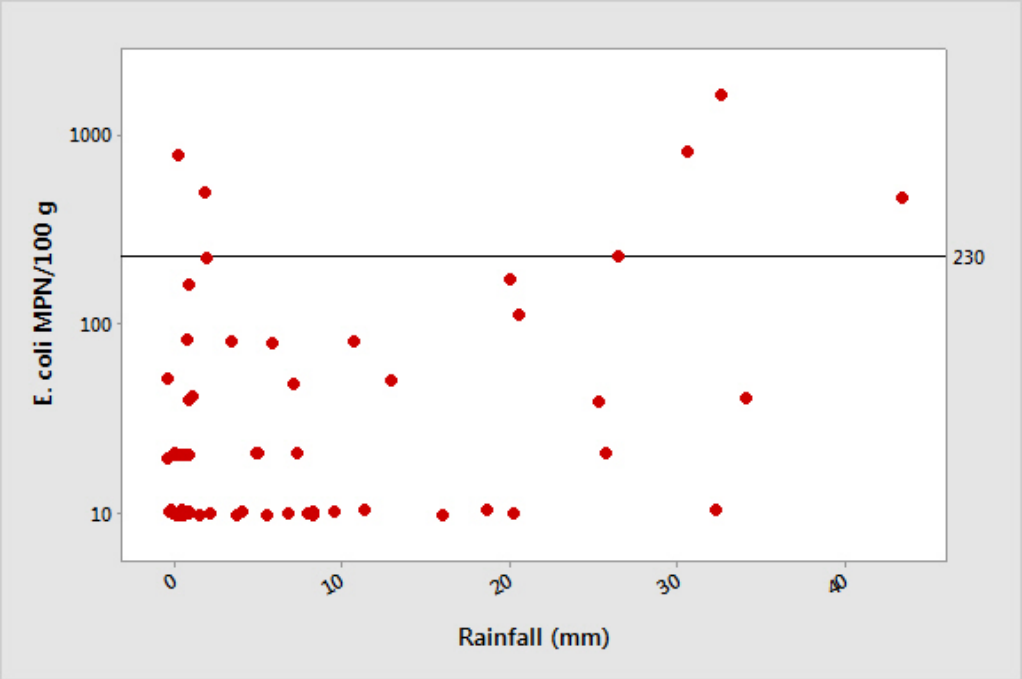


Figure 11.5 Scatterplot of *E. coli* results against rainfall in the previous two days at Loch Slapin

A statistically significant correlation was found between *E. coli* results and the previous two day rainfall (Spearman's rank correlation r = 0.260, p = 0.047). The proportion of results yielding results of <20 *E. coli* MPN/100 g decreased with increasing rainfall.

11.4.2.2 Seven-day rainfall

The effects of heavy rainfall may take differing amounts of time to be reflected in shellfish sample results in different system, the relationship between rainfall in the previous seven days and sample results was investigated in an identical manner to the above. Rainfall data was available for 59 of the 64 sampling occasions. A scatterplot of *E. coli* results against total rainfall recorded for the seven days prior to sampling at Loch Slapin is shown in Figure 11.6. Jittering was applied to the symbols at 0.02 (x-axis) and 0.001 (y-axis) respectively.

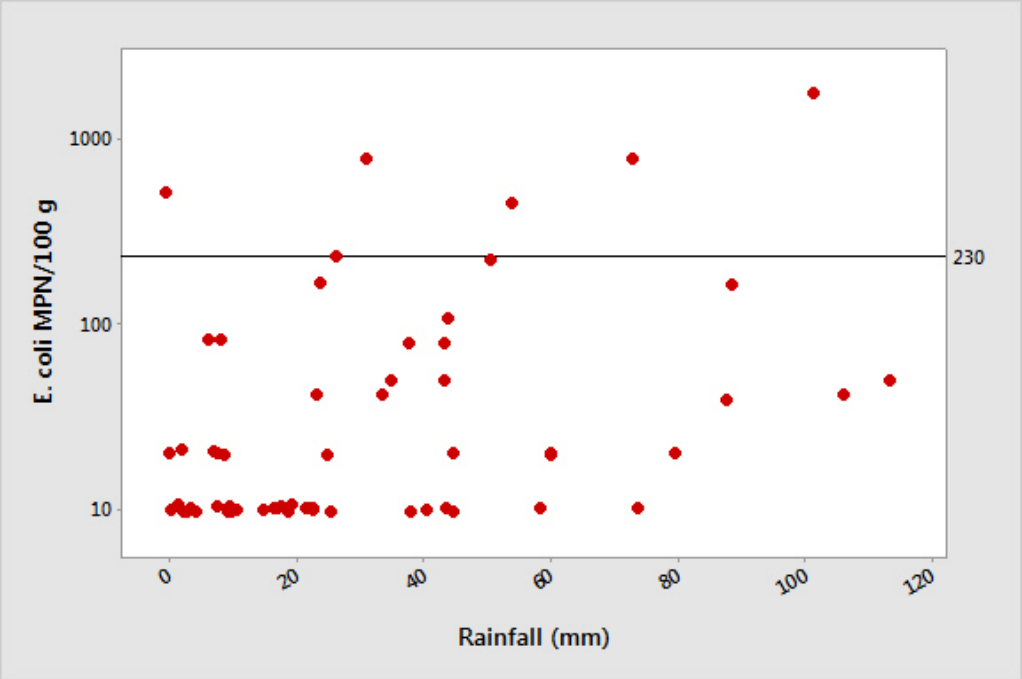


Figure 11.6 Scatterplot of *E. coli* results against rainfall in the previous seven days at Loch Slapin

A statistically significant correlation was found between *E. coli* results and the previous seven day rainfall (Spearman's rank correlation r = 0.391, p = 0.002). Again, the proportion of results yielding results of <20 *E. coli* MPN/100 g decreased with increasing rainfall.

11.4.3 Analysis of results by tidal height

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 moon about 45^{o}, then decreases to the smallest neap tides at about 225^{o}, before increasing back to spring tides 0^{o}. A polar plot of *E. coli* results against the lunar cycle is shown for Loch Slapin in Figure 11.7. It should be noted local meteorological conditions (e.g. wind strength and direction) can also influence tide height, but is not taken into account in this section.

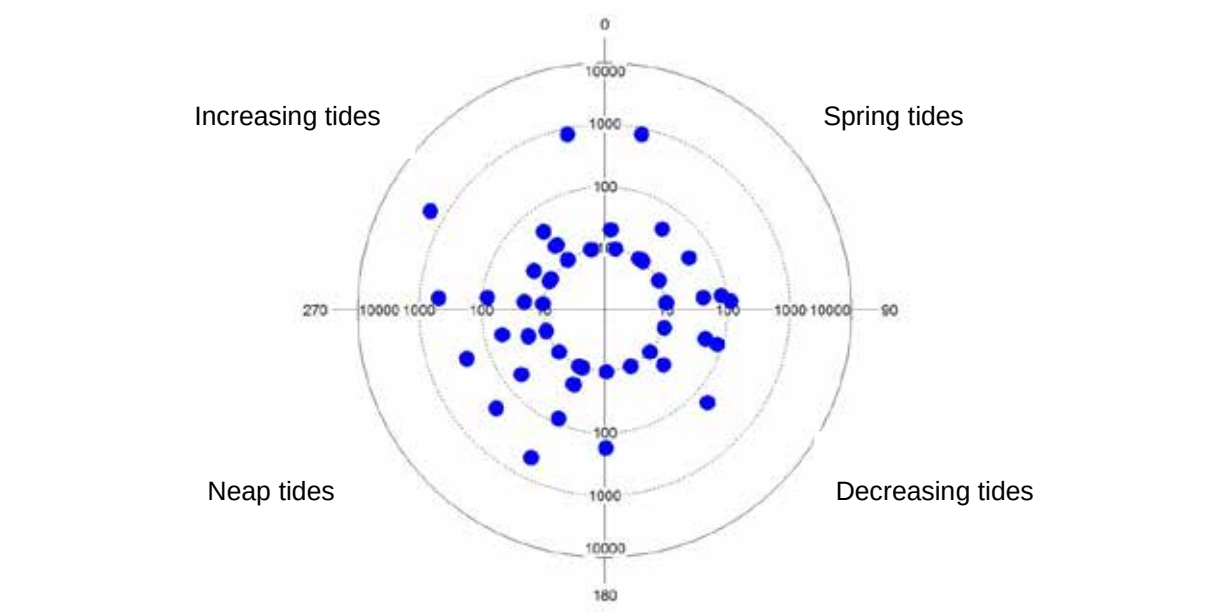


Figure 11.7 **Polar plots of *E. coli* results on the spring/neap tidal cycle at Loch Slapin**

No statistically significant correlation was found between $\log_{10}$ *E. coli* results and the spring/neap tidal cycle (circular-linear correlation r = 0.080, p = 0.677).

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 Slapin is shown in Figure 11.8. High water is at 0^o 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 5 km to the west) and it is assumed that tidal state will be similar between sites.

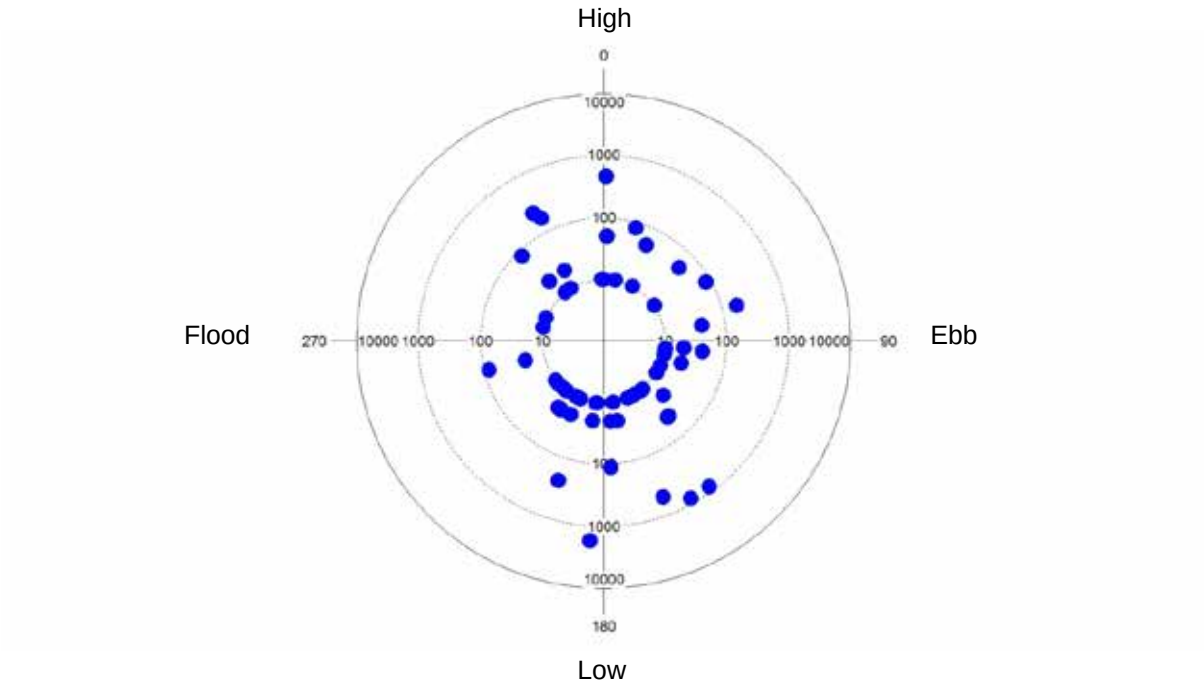


Figure 11.8 Polar plots of $_0$ *E. coli* results on the high/low tidal cycle at Loch Slapin

No statistically significant correlation was found between $\log_{10}$ *E. coli* results and the high/low tidal cycle (circular-linear correlation r = 0.09, p = 0.643).

11.4.4 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 53 out of the 64 Loch Slapin samples. A scatterplot of *E. coli* results against water temperature for Loch Slapin is shown in Figure 11.9. Jittering of symbols was applied at 0.02 (x-axis) and 0.001 (y-axis) respectively.

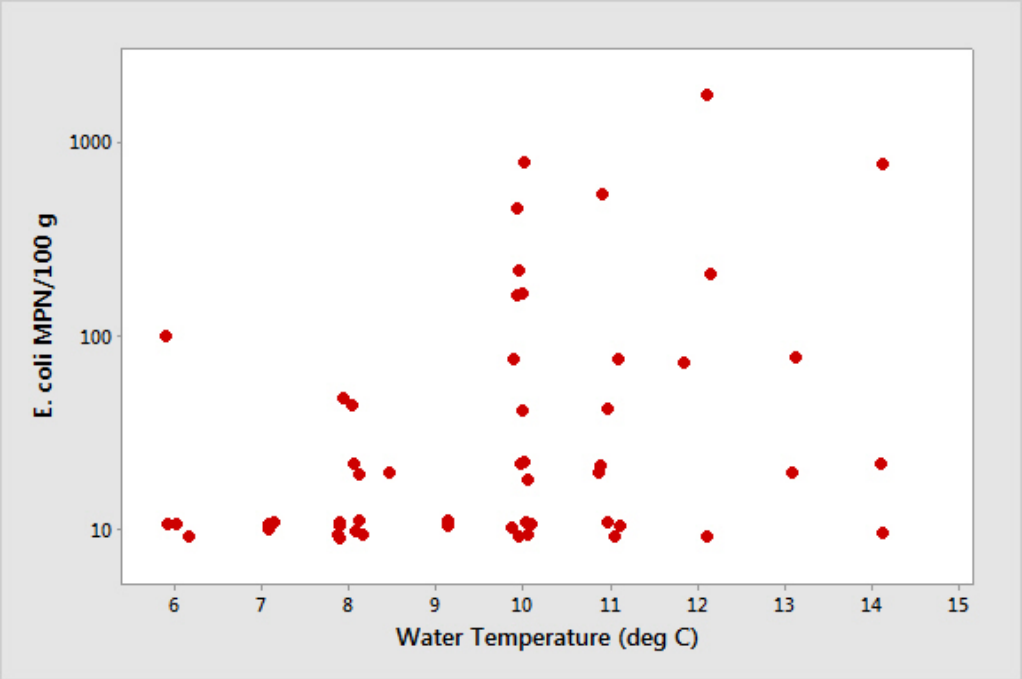


Figure 11.9 Scatterplot of *E. coli* results against water temperature at Loch Slapin

A statistically significant correlation was found between *E. coli* results and water temperature (Spearman's rank correlation r = 0.400, p = 0.003). The results ≥230 *E. coli* MPN/100 g were taken at sea water temperatures between 10 and 14°C.

11.4.5 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence and hence freshwater borne contamination at a site. Too few salinity measurements were taken to support analysis in this report.

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

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

Table 11.2 Loch Slapin 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)
17/05/2011	790	NG 572 178	14.2	71.9	10	35	Spring	Ebb
24/10/2011	1700	NG 572 178	32.7	99.4	12	-	Increasing	Low
14/05/2012	460	NG 5695 1809	39.8	51.4	10	-	Neap	High
13/08/2012	490	Unverified	7.8	7.8	11	-	Increasing	Ebb
20/08/2013	790	NG 572 178	1.0	32.5	14	-	Increasing	Ebb

-No data available

The four highest sample results were taken in May, August and October. The sampling location reported for three of the samples lay to the southeast of the current mussel farm

location. Rainfall levels in the two days prior to sampling was moderate to high for three of the sampling occasions while rainfall in the seven days prior to sampling was moderate to high for four of the sampling occasions. Water temperature varied between 10 and 14^{o}C. Salinity was only recorded for one of the samples and was at 35 ppt.

Three of the five elevated results were from samples taken on increasing tides and one on a spring tide. Three out of the five samples were taken on ebb tides.

11.6 Summary and conclusions

Historical sample results at Loch Slapin have been predominantly low over the 2009-2014 sampling period: only five samples taken during the assessment period had results >230 *E. coli* MPN/100 g. The actual location of sampling for a large proportion of samples was not clear. No statistically significant difference was found between results and season. However, results ≥ 230 *E. coli* MPN/100 g were seen from May to October and there was a significant correlation between *E. coli* results and water temperature. There was a significant correlation between *E. coli* results and rainfall both 2 and 7 days prior to sampling and the higher results were seen from samples taken after rain. These results also tended to be associated with increasing ebb tides although no statistically significant correlation was found between high/low tide and results or spring/neap tides and results.

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 Slapin Shellfish Water Protected Area (SWPA) has the same boundaries as the previous Loch Slapin Shellfish Growing Water (SGW). The SWPA designation covers the majority of the loch. The designated SWPA for Loch Slapin is shown in Figure 12.1. Since 2007, assessment of the bacteriological status of shellfish waters has been undertaken using the shellfish hygiene *E. coli* data and this data has been reviewed in Section 11.

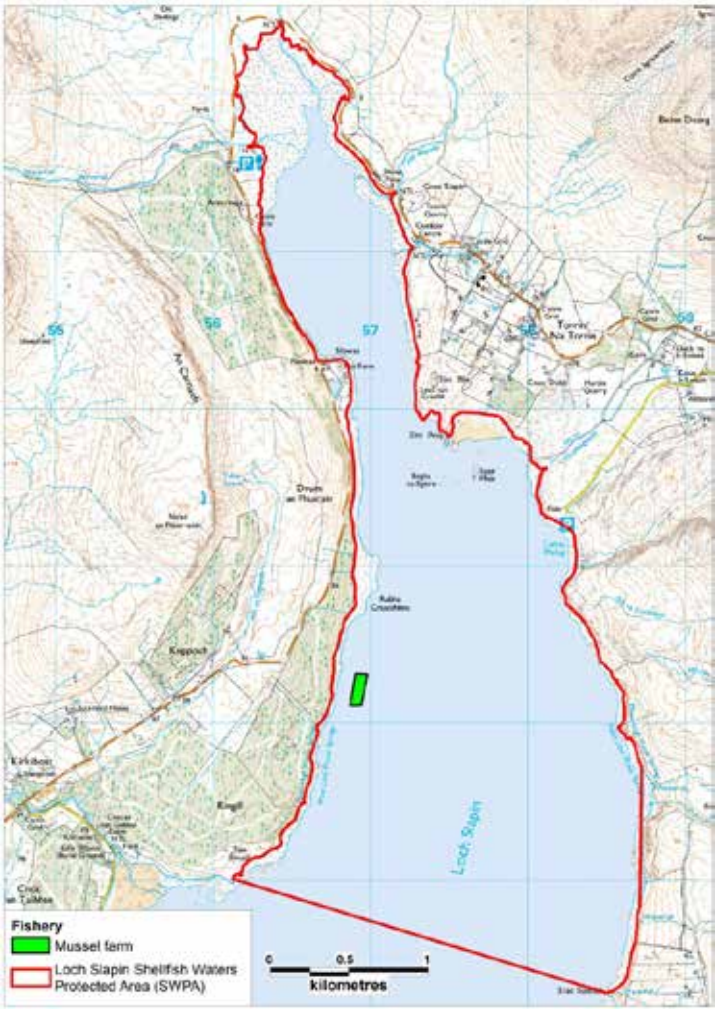


Figure 12.1 Designated shellfish water protected area – Loch Slapin

Bathing Waters

There are no designated bathing waters within Loch Slapin.

13. Bathymetry and Hydrodynamics

13.1 Study Area

Loch Slapin is situated on the southwest coast of the Isle of Skye in the Highland district of the west coast of Scotland. The surroundings at the head of the loch are mountainous, with the peaks Blàbheinn and Garbh-bheinn to the west and Beinn Dearg Mhòr and Beinn Dearg Bheag to the east. The assessment area lies in a sparsely populated region away from industrial activities and agriculture. At its mouth, Loch Slapin joins with neighbouring Loch Eishort at Rubha Suisnish. Numerous streams and small rivers flow into the loch, including Abhainn an t-Sratha Mhòr at the head of the loch; Allt na Dunaiche and Abhainn Cille Mhaire to the west of the loch; Allt an t-Stratha Bhig, Allt na Garbhlain, and Allt A'Ghairuillt to the east. One village, Torrin, is found on the north eastern shore of Loch Slapin, while the small settlement of Kirkibost borders the loch on the western side.

The assessment area encompasses Loch Slapin, to the north of Rubha Suisnish (southern boundary). It is shown in Figure 13.1 with the assessment area demarcated by the red line. The total length of Loch Slapin is 6.9 km. Loch Slapin is approximately 3 km in width at its southern end, narrowing to 0.5 km at Leac nan Craobh before widening to approximately 1 km at its northern end.

Figure 13.1 Extent of the hydrographic study area

Coordinates for Loch Slapin:

57.169746°N 006.037885°W

OS NG 560160

13.2 Bathymetry and Hydrodynamics

13.2.1 Bathymetry

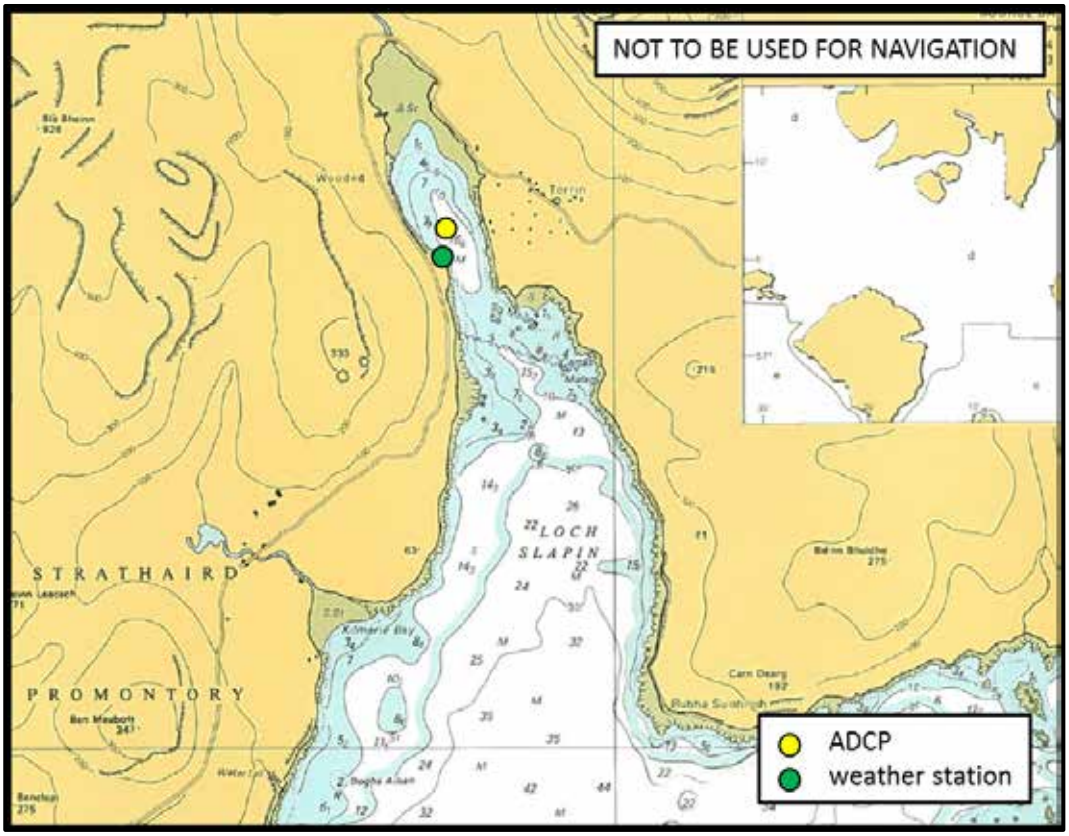


Figure 13.2 Admiralty chart (2208, Edition 12 year 1992) extract for Loch Slapin. ADCP and weather station within assessment area is shown.

Figure 13.2 shows the bathymetry of Loch Slapin. One sill is found in the loch, extending from Leac nan Craobh, 500 m south of the slipway at Faoilean (see Figure 13.1). The sill is 500 m in width at high water, and has a mean depth of 3 m and a maximum depth of 7 m (Edwards & Sharples, 1986). The basin to the north of this sill has a maximum depth of 17 m. To the south of the sill, bathymetry deepens toward the mouth of the loch, where depths of approximately 35 m are reached at the assessment area boundary.

The mean depth of the assessment area at low water is 6.1 m, while the estimated low water volume is 9.9×10^6 m^3 (Edwards & Sharples, 1986).

There is a fairly extensive intertidal area at the head of Loch Slapin 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 Slapin do not exist, and the nearest locations with data to permit tidal predictions are Camus Nan Gall, Isle of Soay, located approximately 10 km west of the survey area boundary [http://easytide.ukho.gov.uk], and Bay of Laig, Isle of Eigg, approximately 28 km to the south of Loch Slapin [www.pol.ac.uk/appl/poltips3].

Standard tidal data for Camus Nan Gall, centred around the survey date of 30th April 2014, are shown in Figure 13.3. Only high water predictions are available for Camus Nan Gall. To illustrate the full tidal curve, data for Bay of Laig, Isle of Eigg, are shown in Figure 13.4 for the same period.

Although data for Loch Slapin are not available, tidal predictions presented for Camus Nan Gall and Bay of Laig (spanning the geographic area) show, that in this region the tidal characteristics are semi-diurnal, with a well-developed spring-neap cycle. Similarity between the tidal characteristics shown in these two curves suggests that tides in Loch Slapin would closely approximate this pattern. The timing of high and low tides in the inner part of Loch Slapin will be slightly later than indicated in Figures 13.3 and 13.4, as a result of the tidal lag created by the shallow sill in the Loch.

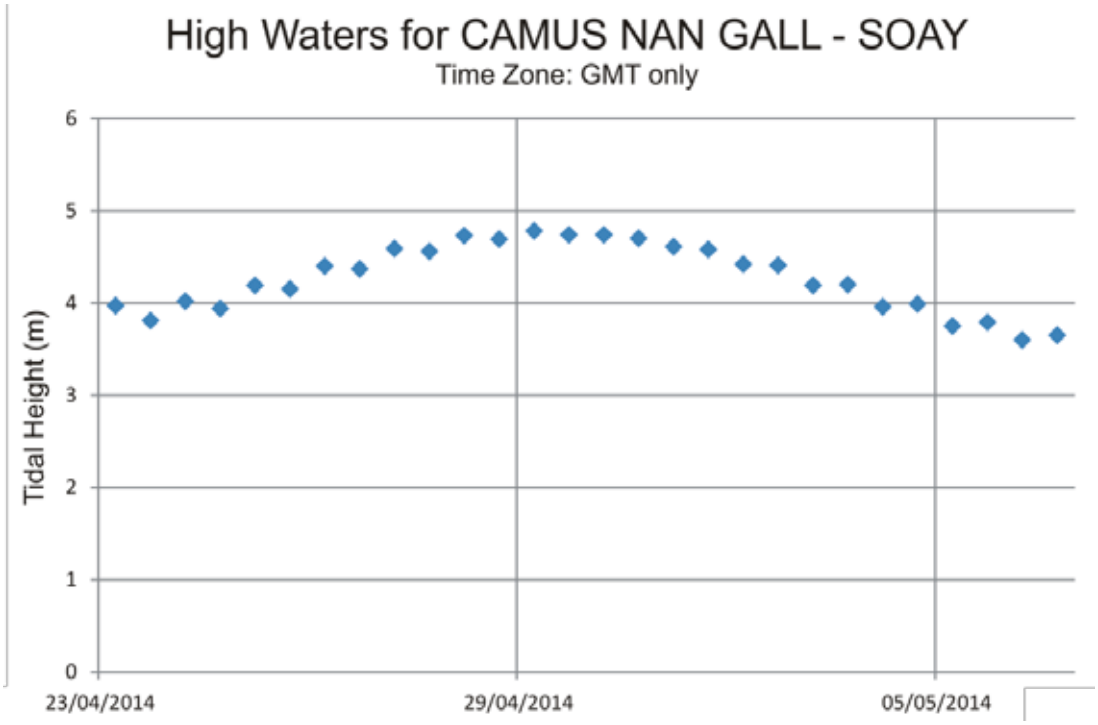


Figure 13.3 Two week tidal curve (high water predictions only) for Camus Nan Gall, Soay.
Reproduced from Poltips3 [www.pol.ac.uk/appl/poltips3]

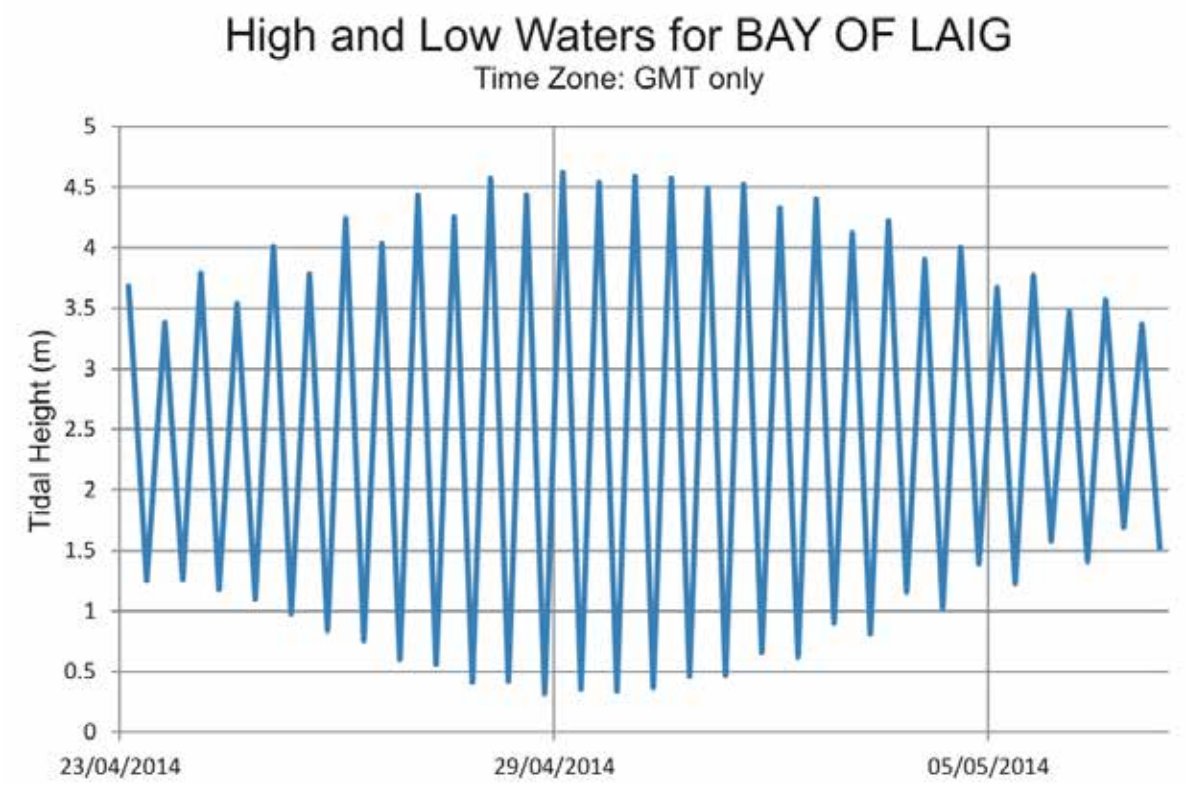


Figure 13.4 – Two week tidal curve for Bay of Laig, Inner Hebrides.
Reproduced from Poltips3 [www.pol.ac.uk/appl/poltips3]

Tidal heights in Loch Slapin, data are from Laurence (1990):

Mean High Water Springs = 4.8 m
Mean Low Water Springs = 0.7 m
Mean High Water Neaps = 3.7 m
Mean Low Water Neaps = 2.1 m

There is also a reported tidal range for Loch Slapin 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: 4.6×10^7 m^3
Neaps: 1.8×10^7 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 along the sill in Loch Slapin.

Current meter data was available at one specified site within the assessment area. Data were obtained from SEPA for a site in the centre of the inner basin of the loch, approximately 350 m to the north of the slipway at Faoilean. This location is shown in Figure 13.5. The survey spanned 15 days between 21 December 2007 and 5th January 2008 (Fish Vet Group, 2008); a half-lunar period, necessary to capture a spring-neap cycle.

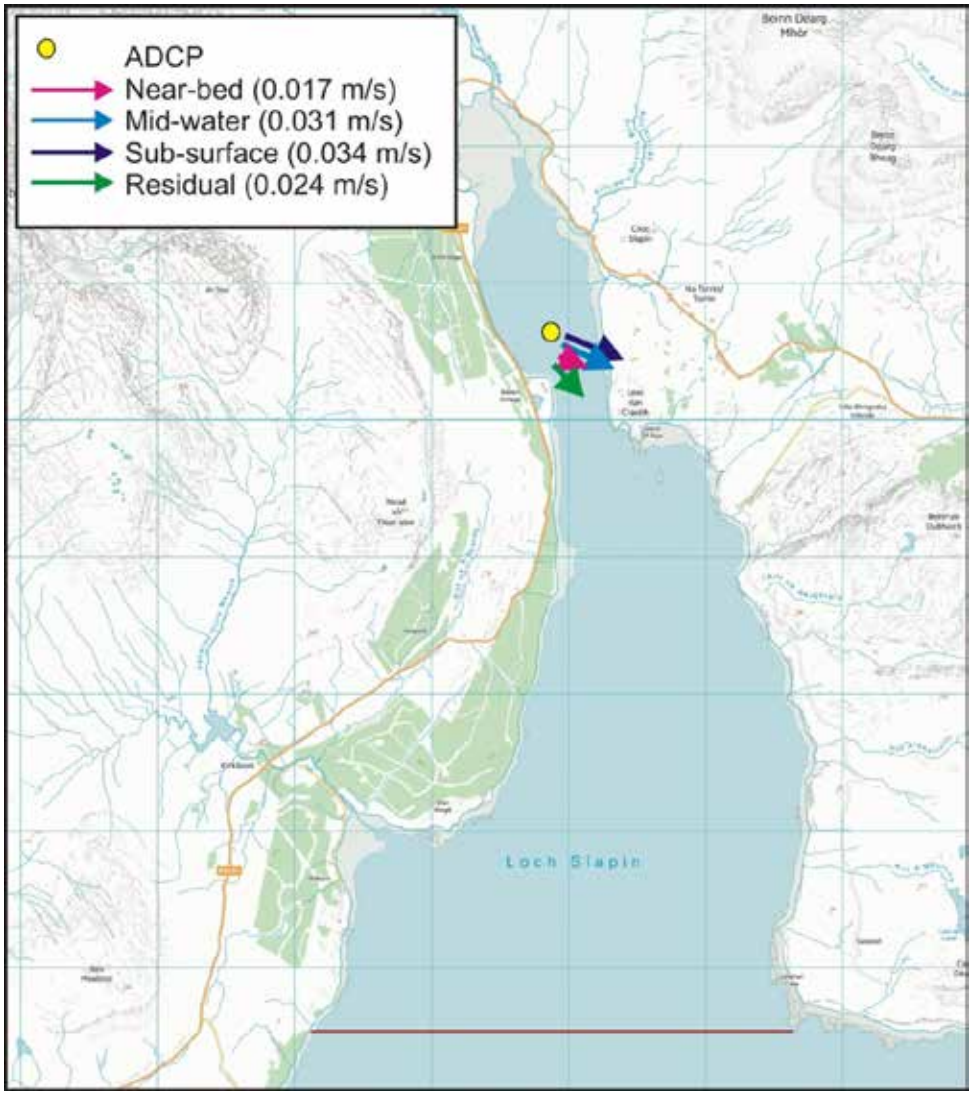


Figure 13.5 Map showing 2008 Loch Slapin sample site within the assessment area. Using the principal current amplitude at each measured depth and the assumption of a uniform sinusoidal tide, the cumulative transport distance and direction that might be expected during each phase of the tide is shown above.

Data from Loch Slapin, NG 56937 E, 20637 N were collected between 21/12/2007 and 05/01/2008 and are summarised in Table 13.1. The average water depth recorded for the duration of the survey was 18.4 m at the ADCP site.

Table 13.1 Loch Slapin current data measured in 2007/2008

Average Depth	Near-bed (2.6 m above seabed)	Mid-water (10.6 m above seabed)	Sub-surface (11.6 m from seabed)
Mean Speed (ms^{-1})	0.0545	0.0540	0.0536
Maximum Speed (ms^{-1})	0.176	0.287	0.209
Principal Axis Amp & Dir (ms^{-1}) & (^{o}M)	0.017 (111)	0.031 (115)	0.034 (112)
Residual speed (ms^{-1})	0.024	0.016	0.016
Residual direction (^{o}M)	137	155	151

Calculated mean current speeds suggest that there is little variation in flows through the water column. The strongest currents at this site are most frequently characterised by flows along a south easterly – north westerly axis, with strongest flows occurring on the ebb, in a south easterly direction. Residual currents are strongest at the seabed, also in a south easterly direction. No distinct pattern was observed in current flows over the spring-neap cycle.

A weather station was also deployed during the Loch Slapin survey. Hourly wind speeds rarely exceeded 10 m/s, averaging 4.35 m/s, or a gentle breeze. Wind directions varied, but were most often from a north easterly direction.

In general, the current meter data from Loch Slapin indicates weak to moderate flows suggesting that the loch varies from being rather quiescent to moderately flushed.

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 2007/2008 Loch Slapin site as 0.43 km (based on a surface principal current amplitude of 0.034 m/s). 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 Slapin. Without such data it is difficult to judge what the dispersive environment might be like. However, dispersion is likely to be enhanced by flows around the shallow sill and tidally exposed rocks in the upper portion of Loch Slapin.

Dispersion of surface contaminants may be enhanced by wave energy within Loch Slapin. Sources of wave energy are from both short period waves generated within the Loch itself and longer period swells originating from the waters to the west and south which are open to the North Atlantic Ocean.

13.2.4 River/Freshwater Inflow

Two small rivers flow into Loch Slapin: Abhainn an t-Sratha Mhor, via Loch na Sguabaidh at the northern end of the loch, and Abhainn Cille Mhaire, which flows into the western side of the Loch at the small settlement of Kirkibost. Numerous other small rivers flow into the study area from the surrounding hillsides, including Allt na Dunaiche, Allt an t-Srath Bhig, Allt Slapin, Allt nan Leac, and Allt a'Mhuillin.

The annual precipitation in the area is approximately 2600 mm and the annual freshwater runoff is estimated as 102.2 M m^3 yr^{-1} (Edwards & Sharples, 1986). The ratio of fresh water flow to tidal flow is moderate at approximately 1:40 (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 16 km to the northeast 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 distance between these two locations and varying topography, wind statistics may not be directly transferrable to the specific production area in Loch Slapin. They are, however, valuable in providing the general pattern of the seasonal wind conditions. Wind roses for this station are presented in Section 9. Wind direction in Loch Slapin 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 Slapin 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 Slapin 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 13.2

Table 13.2 Summary of annual mean parameter values from the box modelling exercise.

Parameter	Value
Tidal Volume Flux ($m^3 s^{-1}$)	34.6
Estuarine Circulation Volume Flux ($m^3 s^{-1}$)	51.8
Median Flushing Time (days)	1.3
95%-ile Flushing Time (days)	1.7

The ratio of tidal volume flux to estuarine circulation volume flux is close to 1 so the tidal and estuarine exchange rates are comparable. Where values are greater than 2 it indicates 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 1.3 days compared to the tidal prism estimate of 1.0 days (Marine Scotland, 2012). The close agreement confirms that this assessment area is effectively flushed in a short period of time.

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 at the head of loch, in the north of the assessment area. However, 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 which will mean that the estuarine exchange has a seasonal variation also.

The loch is relatively small such that there is unlikely to be much variation in properties of the flow across the width of 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 southern part of the assessment area.

From the current meter record in the inner basin of the assessment areas the tidal flow appears to be broadly aligned with the axis of the loch with tide flowing into the loch on the flood and out of the loch on the ebb. It is probably inappropriate to extrapolate observations from the inner basin of Loch Slapin to the broader and deeper outer basin given the relatively broad and shallow sill that separates them. There is potential for a weak cyclonic (anti-clockwise) circulation in the outer basin of the loch but there is little evidence to support this. The cumulative transport distance on each phase (flood/ebb) of

the tide has been estimated at around 0.4 km based on data from the inner basin. It is likely to be a similar order of magnitude in the outer basin.

The residual flows during the period of measurement in the inner basin are found to be relatively weak, suggesting 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 north, and during periods of heavy rainfall and runoff. 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. Indeed prevailing winds from the S/SW quadrant will tend to suppress surface flows and increase mixing.

Net transport of contaminants is related to the residual flow documented in Table 13.1. The residual flow in the surface waters of the assessment area is likely to be highly variable and related to variation in the local wind and freshwater conditions. Using a value of residual flow speed at the surface measured in 2007/8 (0.016 m/s), the net transport over a tidal cycle of approximately 12 hours would be around 0.7 km. This is the same order of magnitude as the transport from tidal flow. It is difficult to assess the magnitude of residual flow in the outer basin due to lack of data.

From the limited current meter measurements in Slapin it is likely that any surface contaminant in the inner part of the loch would be transported primarily along the axis of the loch. 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 north are shown to be less common than from the south. Similarly, exchange rates may be reduced during strong up-loch winds from the south, which are considerably more prevalent. Therefore, whilst the tidal speeds may indicate rather moderate flushing the relatively small volume of the loch and the short flushing time suggest that the surface waters of the assessment area can be described as being ‘well flushed’, noting the potential for reduced flushing efficiency due to prevailing winds.

There is a very limited amount of available current meter data for Loch Slapin 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 Loch Slapin shoreline survey was carried out on the 29/4/2014, with an additional day on the 18/06/2014 used to collect freshwater samples and measurements. No rainfall was recorded in the 48 hours prior to either survey, with both survey days reporting dry weather and calm sea states. On the 29/4/14, temperature was 16^{o}C and wind was easterly at 2 km/h. On the 18/6/14, temperature was 18^{o}C respectively and wind was light in a north-westerly direction.

The fishery consisted of six common mussel lines, 200 m long, with 6 m droppers. Harvest takes place year round where possible. At the time of the survey there was limited stock, as natural spat settlement had failed over the past three years. The lines were also undergoing maintenance work, with the two middle lines being refurbished. Mussel samples returned low results of 18 and <18 *E. coli* MPN/100 g, taken from the northwest and southwest of the farm respectively. Neither seawater sample detected the presence of any faecal contamination, with results at 0 *E. coli* cfu/100 ml.

The immediate shores around Loch Slapin are largely un-inhabited, with human population confined to the villages of Torrin and Kirkibost on the northeast and southwest shores respectively. A number of B&B's and holiday lets were also noted along both the east and west shores. No sewage discharges were noted during the survey, though a bad smell associated with foamy water was observed to the southwest.

Four boats were noted on the water at Faoilean (southwest), with a fifth on shore and a slipway was noted on the mid west shore where the mussel shore-base is located.

Sheep with lambs were observed at various points across the shoreline, except along the southwest area. A sheep pen was also noted on the northeast shore.

The surrounding land is mostly a mixture of rough moorland and rough grazing. A cleared forest area was also noted on the southwest shore and a quarry was observed on the eastern shore.

Seven watercourses were measured and sampled during the survey, with measurements and samples taken on the 18/06/2014. The largest freshwater input was taken on the mid east shore where livestock and the village of Torrin was located and returned a result of 10000 *E. coli* cfu/100 ml. Another significant input came just north, where livestock were also observed. The majority of other freshwater inputs returned low results between <10 and 140 *E. coli* cfu/100 ml.

Birds were the only wildlife observed during the shoreline survey and included oyster catchers, herons, gulls, crows, cormorants and an eider duck.

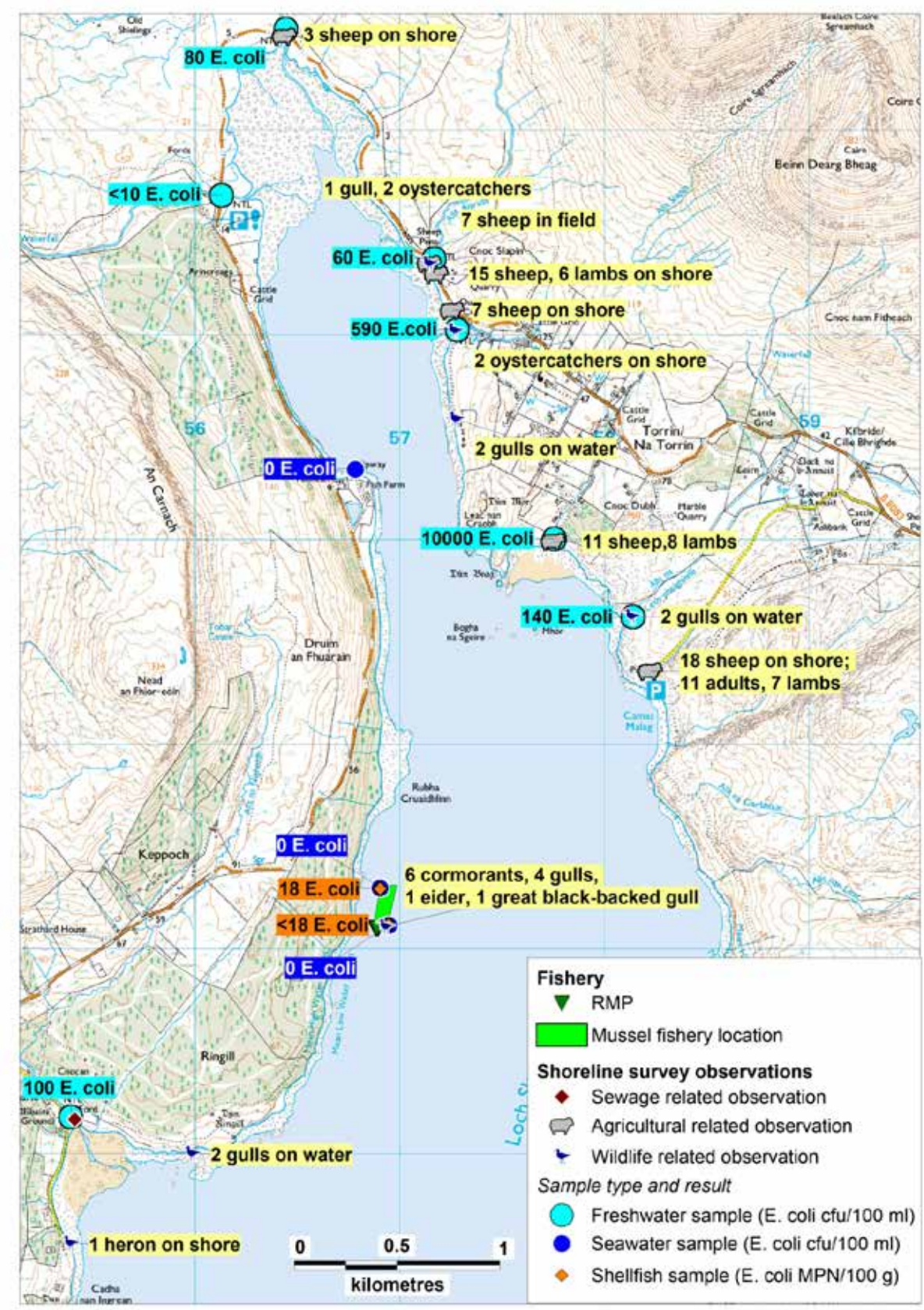


Figure 14.1 Map of shoreline survey observations at Loch Slapin

15. Bacteriological Survey

A bacteriological survey was not undertaken at Loch Slapin due to the fishery consisting of a relatively small single site and the other information available for the assessment of pollution sources in relation to the location of the fishery.

16. Overall Assessment

Human sewage impacts

Human sewage sources are principally associated with the communities of Torrin and Kirkibost approximately 2 km to the northeast and southwest of the fishery respectively. The known sources at Torrin are more numerous. However, two of the septic tanks with the largest PE values are consented to discharge to the Abhainn Cille Mhaire at Kirkibost and these will add to any other faecal pollution within that watercourse.

Agricultural impacts

Identified sources of potential farm animal inputs related to sheep in the vicinity of Tobin. However, the presence of improved grassland was noted in the vicinity of Kirkibost and Suisnish. There was other evidence of potential farm animal presence in those two areas but it is not known whether animals are currently farmed there.

Wildlife impacts

The main potential source of wildlife inputs to the area are the seabirds in the immediate vicinity of the mussel farm. Faecal contamination may also arise from seals, deer and otters. There is no evidence to indicate that one part of the mussel lines will be affected over and above any other.

Seasonal variation

There is a significant proportion of tourist accommodation at Torrin and so sewage inputs from there are likely to be greater in the summer months. Livestock and sea bird numbers are also likely to be higher during that period of the year. Rainfall is greatest during the autumn and winter but faecal contamination in run-off may be greater when high rainfall events occur after dry spells during spring and summer.

No statistically significant difference was seen in the mussel *E. coli* results between seasons. However, all of the higher results in the area (≥230 *E. coli* MPN/100 g) occurred between May and August.

Rivers and streams

Watercourses measured and sampled during the shoreline survey were mainly located on the northeast side of the loch, around the Torrin area. Some of these gave moderately high estimated *E. coli* loadings and, collectively, these would have an effect on the water quality in that area. However, the closest recorded watercourse, Abhainn Cille Mharie, was located at Kirkibost. Although this is identified as receiving the discharge from two of the septic tanks with the largest PEs in the area, the estimated loading was approximately an order of magnitude lower than that of some of the watercourses recorded around Torrin. The results were obtained from samples taken after a relatively dry period: it would be expected that the loadings from watercourses exposed to diffuse pollution would be markedly higher after rainfall.

Salinity data was obtained at two points on the mussel farm. The maximum depth was only 2.8 to 2.9 m. The salinity difference between the sub-surface readings and those at maximum depth was less than 0.4 psu at each point, indicating that there was not a significant impact of freshwater at the surface on the day of the shoreline survey. However, the survey was undertaken after a period of dry weather.

Statistically significant correlations were found between *E. coli* results and rainfall in both the 2- and 7-day periods prior to sampling. This suggests that the fishery is subject to contamination carried in rainfall runoff, which is consistent with the diffuse sources identified previously in this report.

Movement of contaminants

Assessment of available current data indicated that weak to moderate flows occur within the loch with strongest flows on the ebb tide. The predicted transport distance over a single phase of a tidal cycle (ebb or flood) was approximately 0.4 km. The tidal flow appeared to be broadly aligned with the axis of the loch. Net transport over a tidal cycle of approximately 12 hours was estimated to be approximately 0.7 km. Southerly winds will tend to reduce both the ebb and residual transport distances. Movement of contaminants between the upper and lower basins is likely to be restricted to an extent by the sill that lies in the vicinity of Torrin. Depths at the mussel farm are in the region of 14 m so there will be significant dilution of any contamination if mixing occurs. Winds from the prevailing direction (south to southwesterly) are likely to restrict surface flow and enhance mixing.

No statistically significant correlation was found between the mussel *E. coli* results and either spring/neap or high/low tidal cycles. However, the three highest *E. coli* results occurred around spring or increasing ebb tides. This would imply that the sources affecting those results were located to the north of the sampling locations and that the contamination only reaches the mussel farm under certain conditions, such as a greater transport distance to be expected around spring tides.

Temporal and geographical patterns of sampling results

The general level of contamination of the mussels, as indicated by *E. coli*, has remained the same over the period between 2007 and 2014, although no results of <20 *E. coli* MPN/100 g were seen during 2011. This is unusual for the production area.

Uncertainty regarding the exact location from which a large proportion of samples had been taken precluded an assessment of spatial variation of the results.

Conclusions

The principal sources of contamination lie on the northeast shore of the loch, around Torrin, and on the southwest shore around Kirkibost. Those around the Torrin area constitute the largest potential inputs from both human and diffuse sources. The available information indicates that the transport distance may be greater in a southerly direction

than a northerly one, although this will not be the case during strong north winds. Overall, it is likely that the sources around the Torrin area will have a greater impact on water quality at the fishery than those around the Kirkibost area.

17. Recommendations

A map of the recommendations is shown in Figure 17.1.

Production area

It is recommended that the production area be defined as follows: the area within lines drawn between NG 5613 1700 to NG 5875 1700 and between NG 5690 1900 and NG 5831 1900 and extending to MHWS. This excludes the area closer to the identified contamination sources at Torrin. It encompasses the full extent of the mussel farm and Crown Estates lease.

RMP

The recommended location for the RMP is at NG 5694 1828. This is located towards the main identified sources in the area.

Tolerance

The recommended tolerance is 40 m to allow for drift of the lines.

Depth of sampling

A sampling depth of 1-3 m is recommended as there is no evidence for significant stratification within the loch.

Frequency

Monthly sampling should be continued at this site.

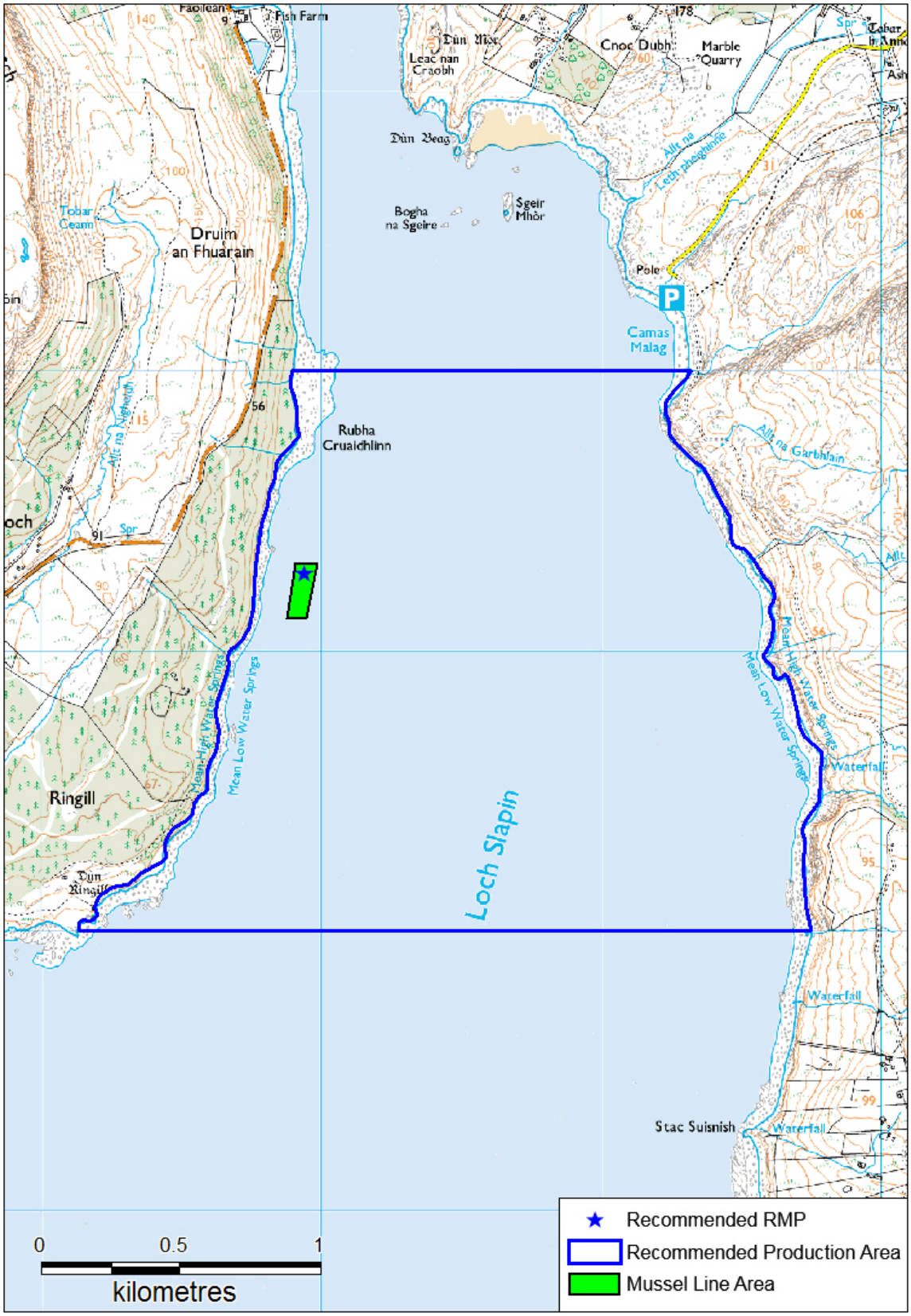


Figure 17.1 Map of recommendations at Loch Slapin

18. References

blaven.com, n.d. *Links.* [Online] Available at: http://www.blaven.com/links.aspx [Accessed 14 07 2014].

Brown, J., 1991. The final Voyage of Rapaiti:A measure of surface drift velocity in relation to the surface wind. *Marine Pollution Bulletin,* 22(1), pp. 37-40.

Burkhardt, W. et al., 2000. Inactivation of indicator microorganisms in estuarine waters. *Water Research,* 34(8), pp. 2207-2214.

Edwards, A. & Sharples, F., 1986. *Scottish Sea Lochs: a Catalogue,* Oban: Scottish Marine Biological Association/Nature Conservancy Council.

Fish Vet Group, 2008. *Report on a Hydrographic Survey, Slapin Fish Farm, Loch Slapin, Skye (NG56937 20637). FVG Ltd. Inverness Scotland,* Inverness: Fish Vet Group.

Gillibrand, P. A., Inall, M. E., Portilla, E. & Tett, P., 2013. A Box Model of Seasonal Exchange Mixing in Regions of Restricted Exchange: Application to Two Contrasting Scottish Inlets. *Environmental Moddeling and Software,* Volume 43, pp. 144-159.

IsleofSkye.com, n.d. *Wildlife.* [Online] Available at: http://www.isleofskye.com/skye-guide/wildlife [Accessed 19 06 2014].

JNCC, 2014. *Seabird colony data.* [Online] Available at: http://jncc.defra.gov.uk/page-4460 [Accessed 23 05 2014].

Lee, R. J. & Morgan, O. C., 2003. Envrionmental factors influencing the microbial contamination of commercially harvested shellfish.. *Water Science and Technology,* Issue 47, pp. 65-70.

Mallin, M. A. et al., 2001. Demographis, landscape and meterological factors controlling the microbial pollution of coastal waters. *Hydrobiologica,* Issue 460, pp. 185-193.

Marine Scotland, 2012. *Locational Guidelines for the authorisation of marine fish farmes in Scottish waters.,* Edinburgh: Produced for Marine Scotland Science by the Marine Scotland Performance Graphics Group.

Skye Birds, 2014. *Bird Sightings on the island of Skye and the neighbouring area.* [Online] Available at: http://www.skye-birds.com/reports/2013/01 [Accessed 03 07 2014].

Skye Birds, 2014. *Cetaceans.* [Online] Available at: http://www.skye-birds.com/gallery/cetaceans/pages/2 [Accessed 03 07 2014].

Unique Cottages, n.d. *Loch Eishort Cabin, Ord, isle of Skye.* [Online] Available at: http://www.unique-cottages.co.uk/cottages/westcoast/skye/loch_eishort_cabin [Accessed 19 06 2014].

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.

References

Alderisio, K. A. & DeLuca, N., 1999. Seasonal enumeration of fecal coliform bacretia from the feces of ring-billed gulls (Larus delawerensis) and Canada geese (Branta canadensis). *Applied and Environmental Microbiology,* 65(12), pp. 5628-5630.

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

Lisle, J. T., Smith, J. J., Edwards, D. D. & McFeters, G. A., 2004. Occurence of microbial indicators and Clostridium perfringens in wastewater, water coloum samples, sediments, drinking water and weddel seal faeces collected at McMurdo Station, Antarctica. *Applied and Environmental Microbiology,* 70(12), pp. 7269-7276.

Poppe, C. *et al.*, 1998. Salmonella typhimurium DT104: a virulent and drug-resistant pathogen. *The Canadian Veterinary Journal,* 39(9), pp. 559-565.

Scottish National Heritage, n.d. *Otters and Development.* [Online] Available at: http://www.snh.org.uk/publications/on-line/wildlife/otters/biology.asp [Accessed 10 10 2012].

Stoddard, R. A. *et al.*, 2005. Salmonella and Campylobacter spp. in Northern Elephant Seals, California. *Emerging Infections Diseases,* 11(12), pp. 1967-1969.

2. Tables of Typical Faecal Bacteria Concentrations

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

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

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

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

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

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

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

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

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

Source: (Gauthier & Bedard, 1986)

References

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

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

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

3. Statistical Data

One-way ANOVA: Log_EC 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	1.098	0.3659	1.09	0.360
Error	60	20.113	0.3352		
Total	63	21.210			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.548274	6.07%	0.75%	0.00%

Means

Season	N	Mean	StDev	95% CI
1	17	1.321	0.584	(1.055, 1.588)
2	14	1.644	0.694	(1.350, 1.938)
3	11	1.394	0.417	(1.063, 1.726)
4	15	1.318	0.420	(1.035, 1.602)

Pooled StDev = 0.548274

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Season	N	Mean	Grouping
2	14	1.644	A
3	11	1.394	A
1	17	1.321	A
4	15	1.318	A

Means that do not share a letter are significantly different.

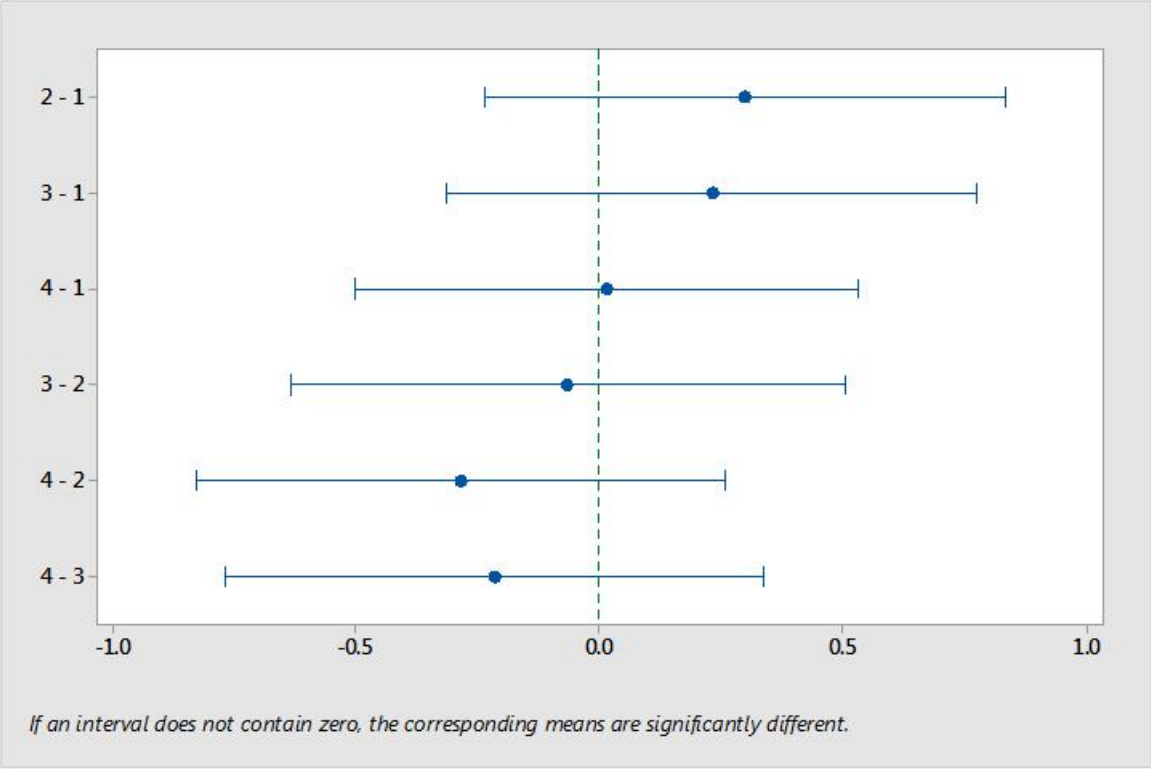


Figure 1 Tukey comparison between Loch Slapin $\log_{10}$ *E. coli* and season

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 Slapin Shoreline Survey Report
Project Name	Shellfish Sanitary Surveys
Client/Customer	Cefas
SRSL Project Reference	00561_B0067
Document Number	B0067_Shoreline 0030

Revision History

Revision	Changes	Date
A	Issue for internal review	14/05/2014
01	First formal issue to Cefas	27/05/2014
02	Second issue to client with comments incorporated from Issue 01	19/06/2014

	Name & Position	Date
Author	Debra Brennan & Eilidh Cole	06/05/2014
Checked	Andrea Veszelovszki,	17/06/2014
Approved	John Hausrath	17/06/2014

SRSL, Scottish Marine Institute, Oban, Argyll, PA37 1QA, tel 01631 559 470, www.samsrsl.co.uk
Production area: Loch Slapin

Site name:	Cruaidhlinn
SIN:	SL-194-290-08
Species:	Common Mussels
Harvester:	Duncan Henderson / Robert Kelly
Local Authority:	Highland Council: Skye & Lochalsh
Status:	Existing area
Date Surveyed:	29/04/2014
Surveyed by:	Debra Brennan & Eilidh Cole
Existing RMP:	NG 5689 1811

Area Surveyed

The east shoreline of Loch Slapin, from the designated parking area at Camas Malag northwards until just beyond the sheep fank by the river Allt Aisridh.

A short section of the west shoreline at Faoilean.

A longer stretch of shoreline on the west side of Loch Slapin from approximately Cadha nan Ingrean northwards towards the area called Keppoch.

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 48 hours prior to the survey. On the day of the survey the weather was dry with haze in the morning. Temperature was around 16°C with an easterly wind of around 2 km/h. Cloud cover was approximately 95% and the sea state was calm.

Stakeholder engagement during the survey

Prior to the survey both the harvester Mr. Duncan Henderson and the sampling officer Mr. Allan MacDonald were very helpful and provided useful information regarding the survey site and fishery.

On the day of the survey, the survey team met with Mr. Henderson on site and he very kindly took the team out on his boat to collect mussel and seawater samples. He also provided further details regarding the site.

Mr. MacDonald was unavailable to meet with the survey team on the survey day. However, he had met with the team the day before at the neighbouring fishery at Loch Eishort.

Fishery

Common mussels (*Mytilus edulis*) are cultivated within the Loch Slapin fishery. Harvest takes place all year round, where possible; however at present the site has limited stock, as there has been no natural mussel spat settlement for three years.

There are six mussel lines in total, but as there are a limited number of mussels growing on these lines, they are undergoing maintenance work with refurbishment of the two middle lines. The mussel lines are 200m long with 6m droppers. Mussel samples could only be collected from the surface of the droppers due to lack of mature stock.

Sewage Sources

The shellfish farm is located along the southwest shore of Loch Slapin, an area of the shore which is largely uninhabited.

No public facilities, cafés or restaurants surround Loch Slapin and no obvious sewage discharges were observed from any surrounding houses, properties or holiday lets, during the survey.

Seasonal Population

No official campsites or caravan parks were seen in the area surrounding Loch Slapin, however, on the eastern shore at Camas Malag there is a large flat grassy area where one caravan was seen parked up. No hotels were observed in the area surrounding Loch Slapin however, there were a number of B&Bs and holiday lets.

Dwellings around the loch are mainly confined to the villages of Torrin and Kirkibost. The larger village, Torrin, lies on the northeast shore of Loch Slapin and Kirkibost is somewhat smaller and lies to the southwest. Holiday lets and houses are scattered on both the east and west shores.

Mr. Henderson noted that the number of holidays homes and lets around Loch Slapin have increased hugely over the past few years with people outside the local area building new properties, specifically as holiday lets. He also noted that although several holiday homes surround the loch, not all of these are occupied all year round.

Boats/Shipping

There is a slipway at Faoilean where Mr. Henderson has his work station. On the day of the survey, four boats were noted on the water in this area and there was one boat out of the water for maintenance.

Farming and Livestock

No cattle were observed at any point on the shoreline survey. Several sheep often with lambs were observed at various points across the shoreline. They did not appear to be concentrated to any one location and were frequently not confined to fields. The only section of the shoreline where sheep were not observed was at the southwest section where there was an old forestry site next to the shore. A sheep fank was confirmed on the northeast shore however no sheep were present.

Land Use

The land surrounding Loch Slapin is mostly rough grazing for sheep. No industry was observed except for the quarry on the eastern shore. The largest village in the area is Torrin, also on the eastern shore. The land behind the immediate shoreline is steep and mountainous.

Land Cover

The predominant land cover surrounding Loch Slapin is rough moorland. The forestry on the south-western shore has mostly been felled and the land has not been put to any further use since.

Watercourses

Eight watercourses were marked on the survey map to be sampled during the survey. Only one of these was not sampled as there were no obvious signs of any watercourse in the area where it should have been. The largest of the watercourses encountered was at the head of Loch Slapin and was over 20m in width. Four of the other watercourses sampled were of reasonable size ranging between 3.21 m and 5.11 m. Two smaller watercourses were sampled which were 1.75 m and 80 cm wide. Two other watercourses were observed during the survey but not sampled. One was next to another watercourse which was sampled and the other was very small with no pipes or outflows running into it.

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

Wildlife surrounding Loch Slapin was scarce with the exception of birds. Oyster catchers, herons, gulls, crows and small garden birds were observed throughout the day of the survey. Other species included sandpipers, great northern divers, cormorants, as well as one eider.

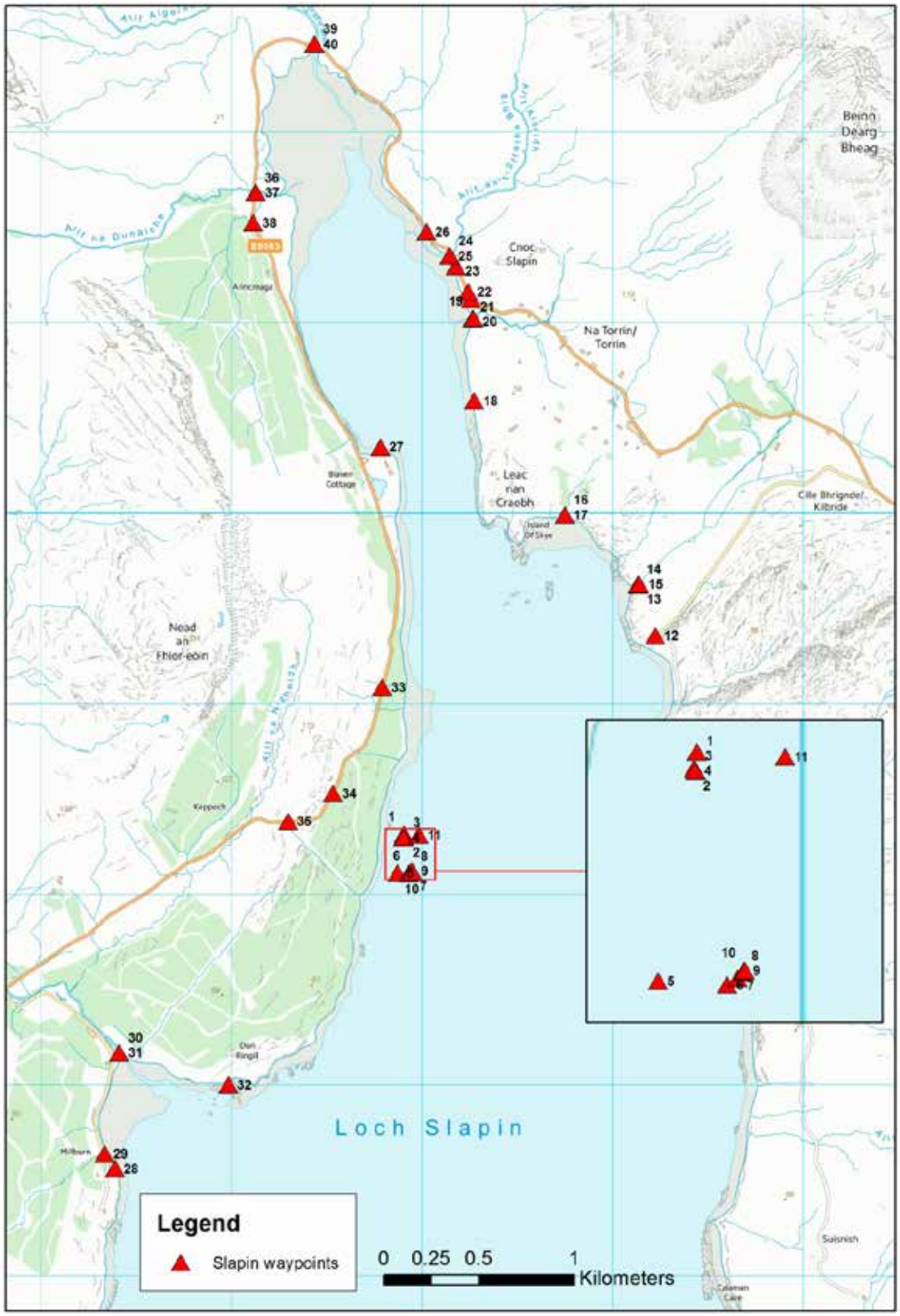


Figure 1. Loch Slapin waypoints

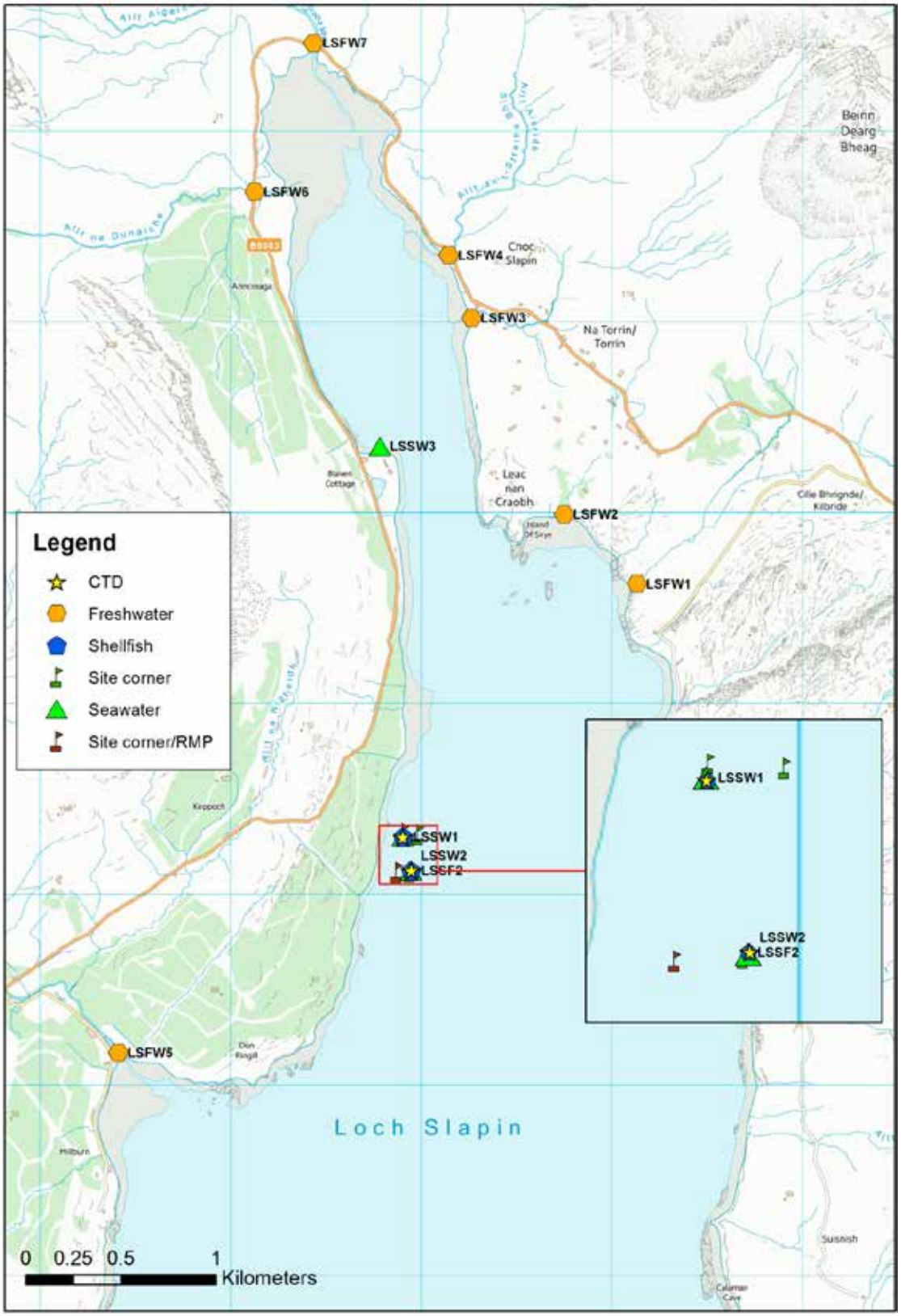


Figure 2. Loch Slapin samples

Table 1 Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
1	29/04/2014	9:41	NG 56906 18315	156906	818316	Figure 3		NW corner of mussel lines at Loch Slapin.
2	29/04/2014	9:41	NG 56903 18301	156904	818301		LSSW1	Planned seawater sample.
3	29/04/2014	9:42	NG 56905 18298	156906	818298		LSSF1	Planned shellfish sample from top of dropper, as mussels very limited.
4	29/04/2014	9:46	NG 56904 18299	156905	818299			CTD cast.
5	29/04/2014	9:49	NG 56872 18113	156872	818113			SW corner of mussel lines at Loch Slapin. Also RMP.
6	29/04/2014	9:51	NG 56932 18110	156933	818110			Six cormorants, four gulls, one eider and one great black backed gull.
7	29/04/2014	9:51	NG 56942 18115	156942	818116			SE corner of mussel lines at Loch Slapin.
8	29/04/2014	9:52	NG 56946 18120	156947	818121		LSSW2	Planned seawater sample.
9	29/04/2014	9:54	NG 56947 18122	156948	818122		LSSF2	Planned shellfish sample from top of dropper, as mussels very limited.
10	29/04/2014	9:56	NG 56948 18122	156949	818123			CTD cast.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
11	29/04/2014	10:00	NG 56984 18311	156984	818311			SW corner of mussel lines at Loch Slapin.
12	29/04/2014	10:14	NG 58224 19357	158225	819357	Figure 4		Start of shoreline walk at Pole on NE shore of Loch Slapin. Eighteen sheep on shore, eleven adults and seven lambs. One caravan parked up.
13	29/04/2014	10:24	NG 58133 19625	158134	819625			River running down from quarry with two gulls on water.
14	29/04/2014	10:24	NG 58133 19626	158133	819626	Figure 5	LSFW1	Planned freshwater sample. Associated with waypoint 15.
15	29/04/2014	10:28	NG 58140 19627	158141	819627	Figure 5		River running to shore with quarry behind. Width = 1.75m, Depth = 26 cm, Flow = 0.003 m/s, SD = 0.002. Associated with waypoint 14.
16	29/04/2014	10:49	NG 57750 19991	157750	819992	Figure 6	LSFW2	Planned freshwater sample. Associated with waypoint 17.
17	29/04/2014	10:51	NG 57750 19990	157751	819991	Figure 6		River running onto shore with house behind. Width = 80 cm, Depth = 21 cm, Flow = 0.017 m/s, SD = 0.009. No signs of pipes. Eleven sheep with eight lambs. Three oyster catchers on shore. Two great northern divers, three common sandpipers and two gulls also on shore. One crow flying overhead. Associated with waypoint 16.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
18	29/04/2014	11:15	NG 57275 20589	157275	820590			Two houses, no pipes or outflows. Two gulls on water.
19	29/04/2014	11:23	NG 57265 21020	157266	821020		LSFW3	Planned freshwater sample. Associated with waypoint 20.
20	29/04/2014	11:27	NG 57271 21021	157271	821021			River running from road to shore. Width = 5.11 m, Depth 1 = 13 cm, Flow 1 = 0.049 m/s, SD 1 = 0.02. Depth 2 = 17 cm, Flow 2 = 0.036 m/s, SD 2 = 0.009. Four houses behind and nearby. No signs of pipes etc. Two oyster catchers and two pigeons on shore. Associated with waypoint 19.
21	29/04/2014	11:32	NG 57258 21120	157258	821120			Seven sheep on shore.
22	29/04/2014	11:33	NG 57243 21160	157244	821161			Drainage under road.
23	29/04/2014	11:35	NG 57179 21295	157180	821296			Fifteen sheep and six lambs on shore.
24	29/04/2014	11:37	NG 57146 21349	157147	821349	Figure 7	LSFW4	Planned freshwater sample. Associated with waypoint 25.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
25	29/04/2014	11:38	NG 57144 21349	157145	821350	Figure 7		Large watercourse running under road onto shore. Width = 4.86 m, Depth 1 = 21 cm, Flow 1 = 0.051 m/s, SD 1 = 0.008. Depth 2 = 31 cm, Flow 2 = 0.029 m/s, SD 2 = 0.01. Seven sheep in field behind next to barn on shore. One gull and two oyster catchers in water. Four boats on water. Associated with waypoint 24.
26	29/04/2014	11:48	NG 57024 21476	157025	821476			Green sheep fank.
27	29/04/2014	12:36	NG 56783 20347	156784	820347	Figure 8	LSSW3	Planned seawater sample from slipway. One boat out of water next to slipway.
28	29/04/2014	12:55	NG 55389 16562	155390	816563			Tigh-na-mara house and two other properties on shore. No pipes/discharges observed. One mooring buoy at sea. Three small garden birds flying overhead. One heron on shore.
29	29/04/2014	13:03	NG 55335 16638	155336	816639			Watercourse running under road onto shore. House nearby, no pipes or signs of outflows, no sample taken.
30	29/04/2014	13:10	NG 55412 17168	155412	817168	Figure 9	LSFW5	Planned freshwater sample. Associated with waypoint 31.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
31	29/04/2014	13:11	NG 55412 17169	155413	817170	Figure 9		Large watercourse running onto shore. Width = 3.92 m, Depth 1 = 17 cm, Flow 1 = 0.201 m/s, SD 1 = 0.007. Depth 2 = 21 cm, Flow 2 = 0.039 m/s, SD 2 = 0.01. Houses behind. Very bad smell. White scum on rocks and dirty looking foam in water. Two blackbirds in trees. Associated with waypoint 30.
32	29/04/2014	13:27	NG 55985 17000	155985	817001	Figure 10		Cliffs next to shoreline. Two seagulls on water.
33	29/04/2014	15:06	NG 56793 19086	156793	819086			End of shoreline walk over very difficult ground.
34	29/04/2014	15:20	NG 56534 18529	156534	818530			Dry stream.
35	29/04/2014	15:25	NG 56297 18383	156298	818383			Stagnant stream.
36	29/04/2014	16:47	NG 56127 21681	156128	821682	Figure 11	LSFW6	Planned freshwater sample. Associated with waypoint 37.
37	29/04/2014	16:49	NG 56130 21681	156130	821681	Figure 11		River running under road onto shore next to car park. Width = 3.21 m, Depth = 16 cm, Flow = 0.549 m/s, SD = 0.021. No wildlife seen. Associated with waypoint 36.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
38	29/04/2014	16:56	NG 56114 21522	156115	821522			Watercourse very close to sampled watercourse at waypoint 36 therefore not sampled. Watercourse runs under road onto shore. Not sampled.
39	29/04/2014	17:05	NG 56436 22462	156436	822462	Figure 12	LSFW7	Planned freshwater sample. Associated with waypoint 40.
40	29/04/2014	17:06	NG 56437 22461	156437	822461	Figure 12		River at head of Loch Slapin. Width = 20.62 m, Depth 1 = 17 cm, Flow 1 = 0.145 m/s, SD 1 = 0.010. Depth 2 = 20 cm, Flow 2 = 0.229 m/s, SD 2 = 0.007. Depth 3 = 10 cm, Flow 3 = 0.061 m/s, SD 3 = 0.002. Three sheep on shore. Associated with waypoint 39.

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

Sampling

Seawater and freshwater samples were collected at the sites marked in Figure 2. One of the planned freshwater sampling sites had no flow (waypoint 34) and so was not sampled.

Due to the misidentification of four of the freshwater samples as contaminated, the watercourses will be re-measured and sampled at a later date and these results will be issued as an addendum to the shoreline survey report. The results presented below are from the original sampling (not the repeat sampling).

Two common mussel samples were taken from the surface of the mussel lines. Samples at depth could not be taken as there were limited mussels growing on the lines due to problems with mussel spat settlement.

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 2.5°C.

Seawater samples were tested for salinity by GSS and the results were reported in mg Chloride per litre. These results have been converted to parts per thousand (ppt) using the 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	29/04/2014	LSSW1	NG 56903 18301	Seawater	0	34.14
2	29/04/2014	LSSW2	NG 56946 18120	Seawater	0	34.14
3	29/04/2014	LSFW1	NG 58133 19626	Freshwater	<1000	N/A
4	29/04/2014	LSFW2	NG 57750 19991	Freshwater	<1000	N/A
5	29/04/2014	LSFW3	NG 57265 21020	Freshwater	<1000	N/A
6	29/04/2014	LSFW4	NG 57146 21349	Freshwater	<1000	N/A
7	29/04/2014	LSSW3	NG 56783 20347	Seawater	0	33.60
8	29/04/2014	LSFW5	NG 55412 17168	Freshwater	<1000	N/A
9	29/04/2014	LSFW6	NG 56127 21681	Freshwater	<1000	N/A
10	29/04/2014	LSFW7	NG 56436 22462	Freshwater	<1000	N/A

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	Sample depth (m)	*E. coli* (MPN/100g)
1	29/04/2014	LSSF1	NG 56905 18298	Mussels	Surface	18
2	29/04/2014	LSSF2	NG 56947 18122	Mussels	Surface	<18

Salinity Profiles

Two CTD profiles were taken, one at the NE end of the site and the second at the SW side of the site. The gathered data will be sent to Cefas as agreed previously on a separate Excel sheet.

Photographs – Please note that the time printed on the photographs is one hour behind real time.

Figure 3. NW corner of mussel lines at Loch Slapin. Associated with waypoint 1.

Figure 4. Start of shoreline walk at Pole on NE shore of Loch Slapin. Eighteen sheep on shore, eleven adults and seven lambs. Associated with waypoint 12.

Figure 5. Planned freshwater sample. River running to shore with quarry behind. Associated with waypoints 14 and 15. Site of LSFW1.

Figure 6. Planned freshwater sample. River running onto shore with house behind. Associated with waypoints 16 and 17. Site of LSFW2.

Figure 7. Planned freshwater sample. Large watercourse running under road onto shore. Associated with waypoints 24 and 25. Site of LSFW4.

Figure 8. Planned seawater sample from slipway. Associated with waypoint 27. Site of LSSW3.

Figure 9. Planned freshwater sample. Large watercourse running onto shore. Houses behind. Very bad smell. Associated with waypoints 30 and 31. Site of LSFW5.

Figure 10. Cliffs next to shoreline. Associated with waypoint 62.

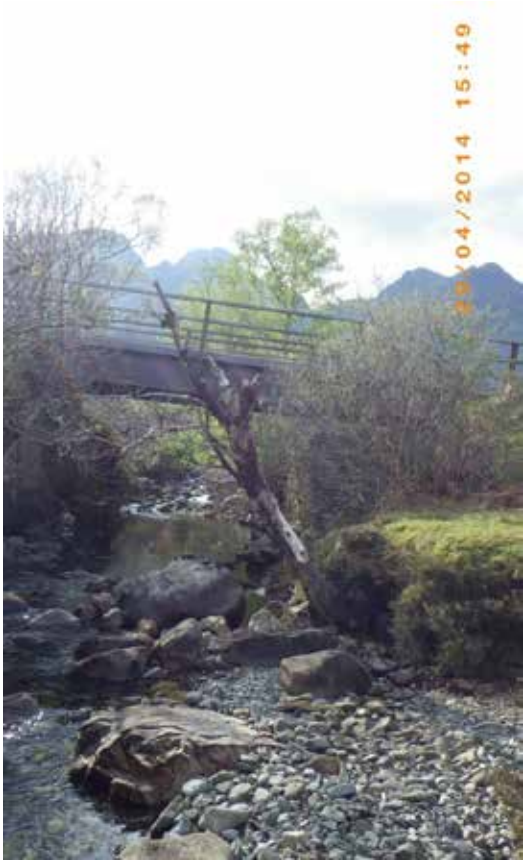


Figure 11. Planned freshwater sample. River running under road onto shore next to car park. Associated with waypoints 36 and 37. Site of LSFW6.

Figure 12. Planned freshwater sample. River at head of Loch Slapin. Associated with waypoints 39 and 40. Site of LSFW7.

6. Shoreline Survey Addendum

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

Document Number	B0067_Shoreline 0030 – Addendum report to original report after resampling of watercourses

Revision 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	Eilidh Cole & Debra Brennan	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 Slapin
Site name:	Cruaidhlinn
SIN:	SL-194-290-08
Species:	Common Mussels
Harvester:	Mr Duncan Henderson / Mr Robert Kelly
Local Authority:	Highland Council: Skye & Lochalsh
Status:	Existing area
Date Surveyed:	18/06/2014
Surveyed by:	Debra Brennan & Eilidh Cole
Existing RMP:	NG 5689 1811

Area Surveyed

This is an addendum to the original report of the survey completed on the 29th April 2014. All freshwater sites were resampled on the 18th June 2014. All new observations are recorded in Table 1 and new sample results recorded in Table 2.

19.1.1 Weather

There was no rainfall recorded 48 hours prior to the survey. On the day of the survey the weather was dry with haze in the morning. Temperature was around 18°C with a very light north-westerly breeze. Cloud cover was approximately 95% which cleared to around 50% by early afternoon. Sea state was calm.

Table 1 Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
1	18/06/2014	9:02	NG 55393 17181	155393	817181	Figure 3	LSFW1	Planned freshwater sample at Loch Slapin SW shore at Kilmarie. Watercourse: Abhainn Cille Mhaire.
2	18/06/2014	9:02	NG 55393 17182	155393	817182	Figure 3		Watercourse running onto shore next to house. Width - 7m 64cm; Depth 1 - 17 cm; Flow 1 - 0.006 m/s; SD 1 - 0.007 (SE bank). Depth 2 - 18 cm; flow 2 - 0.150 m/s; SD 2 - 0.004 (NE bank). Associated with waypoint 1.
3	18/06/2014	9:43	NG 56599 18054	156600	818054			Unsampled, unnamed stream from previous survey found but has dried up and not flowing. Stream has been found higher up the shoreline with some pools of stagnant water. Explains why not found on shoreline previously as not flowing. Sample was not taken due to it being stagnant.
4	18/06/2014	10:11	NG 56129 21684	156130	821684	Figure 4	LSFW2	Planned freshwater sample from Allt na Dunaiche on NW shore next to car park.
5	18/06/2014	10:11	NG 56129 21684	156130	821685	Figure 4		Watercourse running under road onto shore. Width - 4m 22 cm; Depth 1 - 15 cm; Flow 1 - 0.068 m/s; SD 1 - 0.019 (north bank). Depth 2 - 19 cm; Flow 2 - 0.182 m/s; SD 2 - 0.019 (S bank). Associated with waypoint 4.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
6	18/06/2014	10:28	NG 56444 22497	156444	822497	Figure 5	LSFW3	Planned freshwater sample at head of loch from watercourse Abhainn an t-Stratha Mhoir.
7	18/06/2014	10:28	NG 56444 22497	156444	822498	Figure 5		Large watercourse. Width - 11m 33 cm; Depth 1 - 28 cm; Flow 1 - 0.036 m/s; SD 1 - 0.002 (east bank). Depth 2 - 20 cm; Flow 2 - 0.059 m/s; SD 2 - 0.011 (middle of river). Depth 3 - 11 cm; Flow 3 - 0.040 m/s; SD 3 - 0.010 (west bank). Associated with waypoint 6.
8	18/06/2014	10:49	NG 57168 21375	157168	821375	Figure 6	LSFW4	Planned freshwater sample next to sheep pen, Allt Aisridh.
9	18/06/2014	10:49	NG 57168 21374	157168	821375	Figure 6		Watercourse running under road onto shore. Width - 4m 2cm; Depth 1 - 24 cm; Flow 1 - 0.139 m/s; SD 1 - 0.017. Depth 2 - 45 cm; Flow 2 - 0.232 m/s; SD 2 - 0.069. Associated with waypoint 8.
10	18/06/2014	11:03	NG 57282 21027	157283	821028		LSFW5	Planned freshwater sample next to outdoor centre. Watercourse: Allt Slapin.
11	18/06/2014	11:03	NG 57282 21027	157283	821027			Watercourse running alongside outdoor centre onto shore. Width - 5m 35 cm; Depth 1 - 22 cm; Flow 1 - 0.216 m/s; SD 1 - 0.020 (S bank). Depth 2 - 11 cm; Flow 2 - 0.206 m/s; SD 2 - 0.007 (north bank). Associated with waypoint 10.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
12	18/06/2014	11:22	NG 57755 20006	157756	820007	Figure 7	LSFW6	Planned freshwater sample on east shore from unnamed watercourse.
13	18/06/2014	11:23	NG 57756 20005	157756	820006	Figure 7		Watercourse running onto shore below house. Width - 1m 47cm; Depth - 16 cm; Flow - 0.045 m/s; SD - 0.004. Associated with waypoint 12.
14	18/06/2014	12:07	NG 58139 19625	158140	819625		LSFW7	Planned freshwater sample on east shore, north of Pole. Watercourse name: Allt na Leth-pheighinne.
15	18/06/2014	12:07	NG 58140 19625	158140	819625			Watercourse running onto shore with quarry behind it. Width - 2m 30cm; Depth - 19 cm; Flow - 0.062 m/s; SD - 0.010. Associated with waypoint 14.

Figure 1. Loch Slapin Waypoints (resampling).

Figure 2. Loch Slapin samples (resampling).

Sampling

Freshwater samples were re-sampled and collected at the sites marked in Figure 1. One of the planned freshwater sampling sites had no flow (waypoint 16) and so was not sampled.

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	18/06/2014	LSFW1	NG 55393 17181	Freshwater	100	-
2	18/06/2014	LSFW2	NG 56129 21684	Freshwater	<10	-
3	18/06/2014	LSFW3	NG 56444 22497	Freshwater	80	-
4	18/06/2014	LSFW4	NG 57168 21375	Freshwater	60	-
5	18/06/2014	LSFW5	NG 57282 21027	Freshwater	590	-
6	18/06/2014	LSFW6	NG 57755 20006	Freshwater	10000	-
7	18/06/2014	LSFW7	NG 58139 19625	Freshwater	140	-

Photographs

Figure 3. Watercourse running onto shore next to house at Kilmarie. Associated with waypoints 1 & 2. Location of freshwater sample LSFW1.

Figure 4. Watercourse running under road onto shore by car park. Associated with waypoints 4 & 5. Location of freshwater sample LSFW2.

Figure 5. Large watercourse at head of Loch Slapin. Associated with waypoints 6 & 7. Location of freshwater sample LSFW3.

Figure 6. Watercourse running under road onto shore next to sheep pen. Associated with waypoints 8 & 9. Location of freshwater sample LSFW4.

Figure 7. Unnamed watercourse running onto shore below house. Associated with waypoints 12 & 13. Location of freshwater sample LSFW7.

7. SEPA Discharge Consents

Consent Number	Discharge Location	Discharge name	Discharge Type	Discharging to	PE
CAR/L/1001889	NG 54632 17509	Fish Hatchery	Fish Farm Freshwater Tank or Hatchery	Abhainn Cille Mhaire	N/A
CAR/L/1004843	NG 56650 20750	Slapin MCFF, Loch Slapin	Fish Farm Marine Cage	Loch Slapin	N/A
CAR/R/1010087	NG 53940 13250	Dwelling, Glasnakille, Isle of Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1016531	NG 57430 20970	Dwelling, Torrin, Isle of Skye	Sewage (Private) Primary	Land	5
CAR/R/1016644	NG 57860 20790	Dwelling, Torrin, Isle of Skye	Sewage (Private) Primary	Land	5
CAR/R/1020295	NG 61679 13474	Dwelling, Ord, Sleat, Isle of Skye	Sewage (Private) Primary	Soakaway	6
CAR/R/1021878	NG 60583 11819	Dwelling, Tokavaig, Isle of Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1024418	NG 58960 19940	Dwelling, Kilbride, By Broadford	Sewage (Private) Primary	Soakaway	-
CAR/R/1024631	NG 53780 13020	Dwelling, Glasnakille, Elgol, Isle of Skye	Sewage (Private) Primary	Soakaway	15
CAR/R/1024994	NG 59540 11490	Dwelling, Tarskavaig, Isle of Skye	Sewage (Private) Primary	Ob Gauscavaig	5
CAR/R/1028589	NG 55100 18040	Dwelling, Strathaird	Sewage (Private) Primary	Soakaway	15
CAR/R/1032562	NG 61640 13370	Dwelling, Ord, Skye	Sewage (Private) Primary	Soakaway	10
CAR/R/1038308	NG 57490 20840	Dwelling, Torrin, Isle of Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1038309	NG 57500 20790	Dwelling, Torrin, Isle of Skye	Sewage (Private) Primary	Soakaway	8
CAR/R/1039307	NG 57630 20960	Dwelling, Torrin, Isle of Skye	Sewage (Private) Primary	Soakaway	6
CAR/R/1044247	NG 61730 13270	Dwelling, Ord, Isle of Skye	Sewage (Private) Untreated	Soakaway	5
CAR/R/1044444	NG 61660 13430	Dwelling, Ord, Skye	Sewage (Private) Primary	Loch Eishort	5
CAR/R/1045459	NG 57500 20620	Dwelling, Torrin	Sewage (Private) Primary	Soakaway	5
CAR/R/1045616	NG 57670 20550	Dwelling, Torrin, Broadford, Isle of Skye	Sewage (Private) Primary	Land	6
CAR/R/1045634	NG 57617 21050	Dwelling, Torrin, Isle of Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1046374	NG 59040 20120	Dwelling, Kilbride, Broadford	Sewage (Private) Primary	Soakaway	6
CAR/R/1046561	NG 57519 21107	Dwelling, Torrin, Isle of Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1046856	NG 57793 20931	Dwelling, Torrin, Broadford, Skye	Sewage (Private) Primary	Soakaway	8
CAR/R/1047013	NG 59260 20030	Dwelling, Kilbride, Skye	Sewage (Private) Primary	Soakaway	7
CAR/R/1047595	NG 55520 17900	Dwelling, Strathaird, Isle of Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1048141	NG 57573 20985	Dwelling, Torrin,Isle Of Skye	Sewage (Private) Primary	U/T of Loch Slappin	6
CAR/R/1048173	NG 57570 20960	Dwelling, Torrin,Isle Of Skye	Sewage (Private) Primary	Soakaway	6
CAR/R/1049450	NG 57670 21066	Dwelling, Torrin,Isle Of Skye	Sewage (Private) Primary	Allt Slapin	5
CAR/R/1049758	NG 58060 20690	Dwelling, A Chuibheall,Isle Of Skye	Sewage (Private) Primary	Land	8
CAR/R/1050510	NG 61810 13160	Dwelling, Ord, Isle of Skye IV44 8RN	Sewage (Private) Primary	Soakaway	6
CAR/R/1054967	NG 57902 20190	Dwelling, Torrin, By Broadford, Isle of Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1055490	NG 61801 13399	Dwelling, Ord, Teangue, Isle of Skye	Sewage (Private) Primary	Soakaway	6
CAR/R/1055929	NG 61712 13170	Dwelling, Ord Sleat, Isle of Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1056716	NG 61732 13259	Dwelling, Tigh A'chiobair, Isle of Skye	Sewage (Private) Primary	Soakaway	5

CAR/R/1058029	NG 58970 20130	Dwelling, Broadford, Isle of Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1062586	NG 53460 12702	Dwelling, Glasnakille, Elgol, Isle of Skye	Sewage (Private) Secondary	Allt Mor	5
CAR/R/1067379	NG 57740 20390	Dwelling, Torrin, Broadford	Sewage (Private) Primary	Land	5
CAR/R/1068218	NG 61839 13173	Dwelling, Ord, Teangue, Sleat, Isle of Skye	Sewage (Private) Primary	Land	5
CAR/R/1068402	NG 58090 20450	Dwelling, Torrin, Broadford, Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1068406	NG 58040 20498	Dwelling, Torrin, Broadford, Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1068420	NG 58000 20420	Dwelling, Torrin, Broadford,Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1068426	NG 58080 20450	Dwelling, Torrin, Broadford, Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1068435	NG 58100 20460	Dwelling, Torrin, Broadford, Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1069432	NG 57470 20430	Dwelling, Torrin,Broadford,Isle of Skye	Sewage (Private) Primary	Land	5
CAR/R/1069438	NG 57830 20830	Dwelling, Torrin,Broadford,Isle of Skye	Sewage (Private) Primary	Land	5
CAR/R/1070543	NG 58040 20710	Dwelling, Torrin, Isle of Skye	Sewage (Private) Primary	Land	5
CAR/R/1070554	NG 57950 20370	Dwelling, Torrin, Broadford, Isle of Skye	Sewage (Private) Primary	Land	5
CAR/R/1073774	NG 56730 20290	Dwelling, Faoilran, Isle Of Skye	Sewage (Private) Primary	Soakaway	10
CAR/R/1074466	NG 61686 13373	Dwelling, Ord, Teangue, Isle Of Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1075179	NG 57220 21360	Broadford	Sewage (Private) Primary	Soakaway	6
CAR/R/1075180	NG 57200 21320	Broadford	Sewage (Private) Primary	Soakaway	6
CAR/R/1076168	NG 61750 13400	Dwelling, Ord, Teangue, Isle of Skye	Sewage (Private) Primary	Soakaway	7
CAR/R/1076488	NG 60164 11776	Dwelling, Tokavaig, Teangue, Isle of Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1076866	NG 55310 17271	Dwelling, Isle of Skye	Sewage (Private) Primary	Abhainn Cille Mhaire	30
CAR/R/1076932	NG 55383 17092	Dwelling, Isle of Skye	Sewage (Private) Primary	Loch Slapin	5
CAR/R/1076975	NG 61890 13140	Dwelling, Ord, Isle Of Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1077014	NG 61880 13140	Dwelling, Ord Isle Of Skye	Sewage (Private) Primary	Soakaway	6
CAR/R/1077023	NG 54420 14545	Dwelling, Elgol, Isle of Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1077025	NG 54760 17500	Dwelling, Strathaird, Broadford	Sewage (Private) Primary	Soakaway	5
CAR/R/1077029	NG 54807 17458	Dwelling, Strathaird	Sewage (Private) Primary	Abhainn Cille Mhaire	10
CAR/R/1078378	NG 59056 19989	Dwelling, Broadford, Isle of Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1078494	NG 57751 20901	Dwelling, Broadford, Isle of Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1078505	NG 60740 12050	Dwelling, Tokavaig, Sleat, Isle of Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1078600	NG 55053 18016	Dwelling, Strathaird, Isle Of Skye	Sewage (Private) Primary	Soakaway	6
CAR/R/1078768	NG 60240 12060	Dwelling, Tokavaig, Isle of Ornsay	Sewage (Private) Primary	Soakaway	6
CAR/R/1079424	NG 57800 20770	Dwelling, Torrin, Broadford, Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1079470	NG 61790 13383	Dwelling, Ord. Isle of Skye	Sewage (Private) Tertiary	Soakaway	6
CAR/R/1079695	NG 57700 20990	Dwelling, Torrin, By Broadford, Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1079731	NG 61868 13148	Dwelling, Ord,Isle of Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1079742	NG 61702 13221	Dwelling, Ord Sleat, Isle of Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1080192	NG 57790 20117	Dwelling, Torrin,Isle of Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1092097	NG 60340 11660	Dwelling, Tokavaig, Sleat, Skye	Sewage (Private) Secondary	Soakaway	8

CAR/R/1093587	NG 61820 13686	Dwelling, Ord, Sleat, Isle of Skye	Sewage (Private) Primary	Loch Eishort	50
CAR/R/1098516	NG 53640 12630	Dwelling, Elgol, Isle of Skye	Sewage (Private) Primary	Soakaway	6
CAR/R/1103881	NG 57900 20430	Dwelling, Torrin, Isle of Skye	Sewage (Private) Primary	Soakaway	5
CAR/R/1106565	NG 56186 21253	Dwelling, Broadford, Isle of Skye	Sewage (Private) Primary	Mound soakaway	5
CAR/R/1106633	NG 55290 16517	Dwelling, Elgol, Isle of Skye	Sewage (Private) Primary	Soakaway	7
CAR/R/1111122	NG 61702 13074	Dwelling, Ord, Isle of Skye	Sewage (Private) Tertiary	River Ord	6
CAR/R/1111988	NG 61800 13430	Dwelling, Ord, Teangue	Sewage (Private) Primary	Land	5
CAR/S/1019126	NG 57930 21100	Torrin WTW, Torrin, Isle of Skye	Other Effluent Potable Water Treatment and Supply		N/A
CAR/S/1019126	NG 57950 21180	Torrin WTW, Torrin, Isle of Skye	Other Effluent Potable Water Treatment and Supply		N/A
PPC/B/1014383	NG 58373 20114	Torrin Quarry, Torrin, Isle of Skye	Trade Effluent		N/A
CAR/R/1093587	NG 61860 13570	10 Holiday Appartments, Ord, Sleat, Isle of	Sewage (Private) Primary	Loch Eribol	5

LS=Land/Soakaway, SW= Seawater Body, FW= Freshwater Body, PE= Population Equivalent, - = Data not available N/A= Not Applicable

8. Loch Slapin CTD data

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

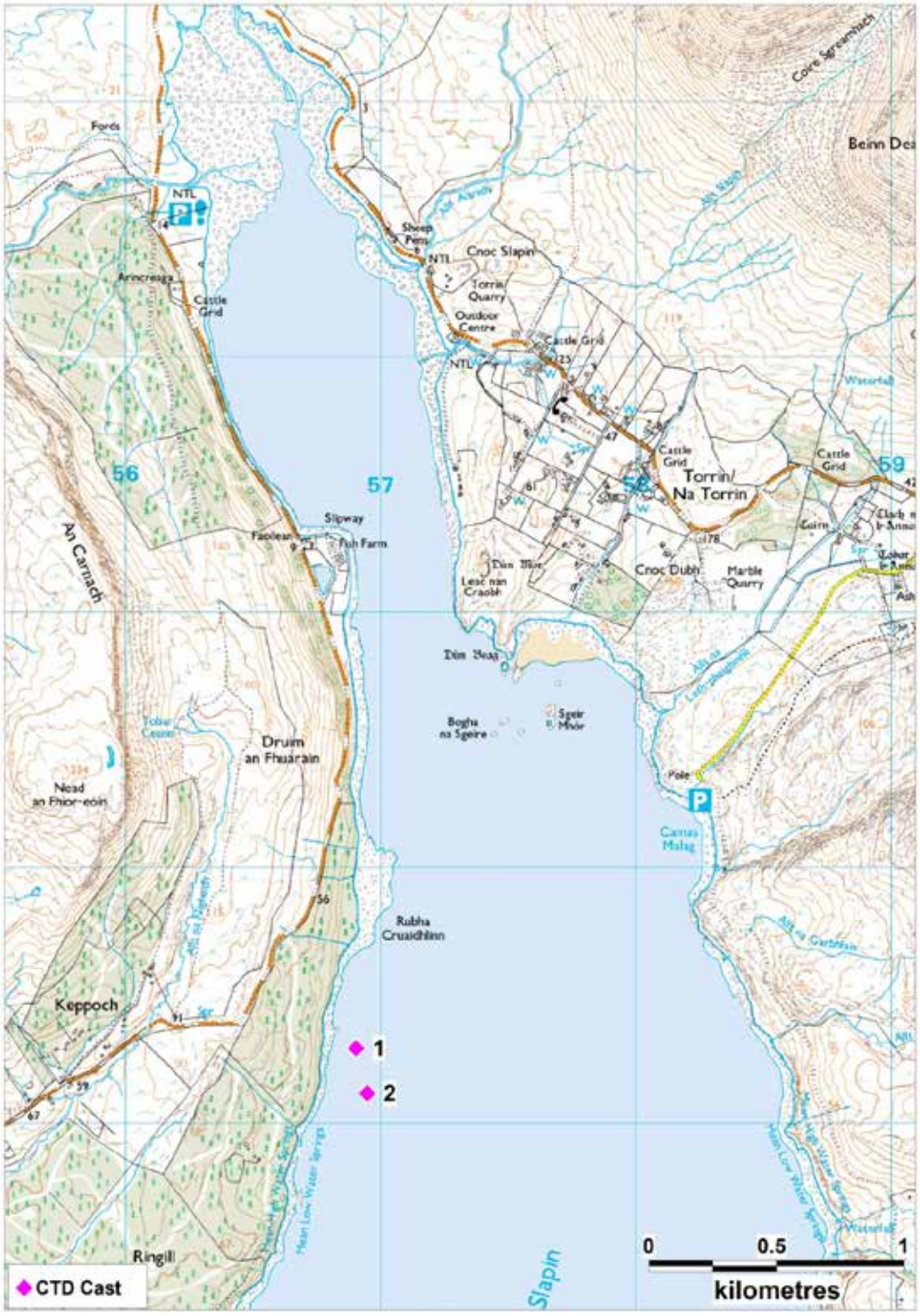


Figure A8.1 Location of CTD casts

CAST 1

Data Header

% Device	10G100653
% File name	10G100653_20140429_084511
% Cast time (local)	29/04/2014 09:45
% Sample type	Cast
% Cast data	Down & up
% Location source	GPS
% Start latitude	57.1907925
% Start longitude	-6.0251736
% Start GPS horizontal error(Meter)	4.400000095
% Start GPS vertical error(Meter)	8.649999619
% Start GPS number of satellites	5
% Cast duration (Seconds)	54.2
% 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)
0.149006875	9.991785113	33.11909272
0.446970298	9.636273312	33.32344589
0.74490343	9.607235178	33.35542567
1.042835345	9.623146585	33.32842153
1.340768039	9.579532593	33.33976149
1.638697719	9.566497183	33.34013057
1.936627554	9.544455975	33.32805714
2.234554681	9.498345793	33.34678534
2.532477235	9.46081068	33.34792188
2.817541341	9.432755675	33.35767298
2.817369576	9.385332628	33.40610579
2.532317984	9.375244993	33.38714268
2.234409304	9.383674343	33.38826189
1.936498508	9.415050163	33.37972639
1.638584603	9.441069379	33.3757614
1.340667911	9.463590781	33.36824067
1.042746922	9.534318189	33.36030228
0.744822192	9.549266956	33.35613033
0.446894703	9.578130217	33.34813951
0.148971169	9.584897543	33.34760208

CAST 2

Data Header

% Device	10G100653
% File name	10G100653_20140429_085708
% Cast time (local)	29/04/2014 09:57
% Sample type	Cast
% Cast data	Down & up
% Location source	GPS
% Start latitude	57.1892362
% Start longitude	-6.0243009
% Start GPS horizontal error(Meter)	5.579999924
% Start GPS vertical error(Meter)	8.020000458
% Start GPS number of satellites	6
% Cast duration (Seconds)	54.4
% 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)
0.14902415	10.10376056	32.99003792
0.447006983	9.653769602	33.3132626
0.744945364	9.616654372	33.32726944
1.042879907	9.586851337	33.33005257
1.340810542	9.546118483	33.34394604
1.638737437	9.522940814	33.34666432
1.936661307	9.494401823	33.35680826
2.234580765	9.468194675	33.37115406
2.532496034	9.459679666	33.38349803
2.891621237	9.460481831	33.39186839
2.891448594	9.460481831	33.39186839
2.532323391	9.459679666	33.38349803
2.234410253	9.451416804	33.38643512
1.936496729	9.450442954	33.38117835
1.638582016	9.455777358	33.37985122
1.340658224	9.479102961	33.31014265
1.04273192	9.499786948	33.36987197
0.744810751	9.514411227	33.36571887
0.446887728	9.533183047	33.36349632
0.148968804	9.573220378	33.36521167