Scottish Sanitary Survey Report

Sanitary Survey Report
Loch Beag
HL-118
June 2015

Cefas

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

Report Title	Loch Beag
Project Name	Scottish Sanitary Survey
Client/Customer	Food Standards Agency Scotland
Cefas Project Reference	C6316A
Document Number	C6316A_2014_8
Revision	V1.1
Date	10/06/2015

Revision History

Revision number	Date	Pages revised	Reason for revision
0.1	13/10/2014	All	Draft report for review
1.0	24/11/2014	Distribution, 9,10,11,18,20,24, 38,45,46,47	Amendments in line with consultation comments and typographical corrections
1.1	10/06/2015	1,32	Update link, correct chart in Figure 11.2

	Name	Position	Date
Author	Jessica Larkham, Frank Cox, Liefy Hendrikz, Ron Lee	Scottish Sanitary Survey Team	10/10/2014
Checked	Michelle Price-Hayward	Principal Shellfish Hygiene Scientist	10/06/2015
Approved	Michelle Price-Hayward	Principal Shellfish Hygiene Scientist	10/06/2015

Centre for Environment, Fisheries & Aquaculture Science, Weymouth Laboratory, Barrack Road, The Nothe, Weymouth DT4 8UB. Tel 01305 206 600 www.cefas.co.uk

Report Distribution – Loch Beag

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
	Stephen Lewis	Sampling Officer
	Ian MacKinnon	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 Beag on the basis recommended in the European Union Reference Laboratory publication: "Microbiological Monitoring of Bivalve Mollusc Harvesting Area Guide to Good Practice: Technical Application" (https://eurlcefas.org/media/13831/gpg_issue-5_final_all.pdf). This areas was selected for survey at this time based on a risk-based ranking amongst those Scottish production areas that had yet to receive a survey.

Loch Beag is a small inlet at the head of Loch nan Uamh, which itself opens at the western end to the Sound of Arisaig, on the west coast of Scotland. The area is very sparsely populated, with the majority of dwellings located along the A830 north and east of Loch nan Uamh, outwith Loch Beag itself.

Loch Beag is classified for the production of common mussels (*Mytilus edulis*), which are cultivated on long-lines at a single site near the south shore of the loch.

There are few identified sources of faecal contamination to the mussel farm in Loch Beag. Those that have been identified fall into two groups. The first is the consented discharges, watercourses and farms located around Loch nan Uamh and to the north and northwest of Loch Beag. These sources have small associated loadings and are further from the shellfish farm than the estimated particle transport distance. The other group of sources are the watercourses and a discharge presumed to be associated a dwelling to the east of the mussel farm. The estimated loadings from these sources are also small but may impact at the farm on an ebb tide.

No changes are recommended to the production area boundaries, however it is recommended that the RMP be moved to NM 7276 8332, closer to the eastern end of the mussel farm, in order to reflect the location of potential contamination sources within Loch Beag. 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 Beag
Site Name	Ardnambuth
SIN	HL-118-215-08
Species	Common Mussels
Type of Fishery	Longline
NGR of RMP	NM 7276 8332
East	172760
North	783320
Tolerance (m)	40
Depth (m)	1-3
Method of Sampling	Hand
Frequency of Sampling	Monthly
Local Authority	Highland Council: Lochaber
Authorised Sampler(s)	Stephen Lewis
Local Authority Liaison Officer	Alan Yates
Production Area	The area bounded by lines drawn between NM 7223 8370 and NM 7200 8319 extending to MHWS

III. Report

1. General Description

Loch Beag is located within the Lochaber district of Highland Council on the west coast of Scotland. The loch comprises a small inlet at the head of Loch nan Uamh, which itself opens at the western end to the Sound of Arisaig. The Ardnish peninsula boarders the loch to the south.

Loch Beag is 1.2 km in length, has a width of approximately 500 m and a maximum recorded depth of 21 m. The loch has a westerly orientation.

The area around Loch Beag is sparsely inhabited with no identifiable settlements.

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

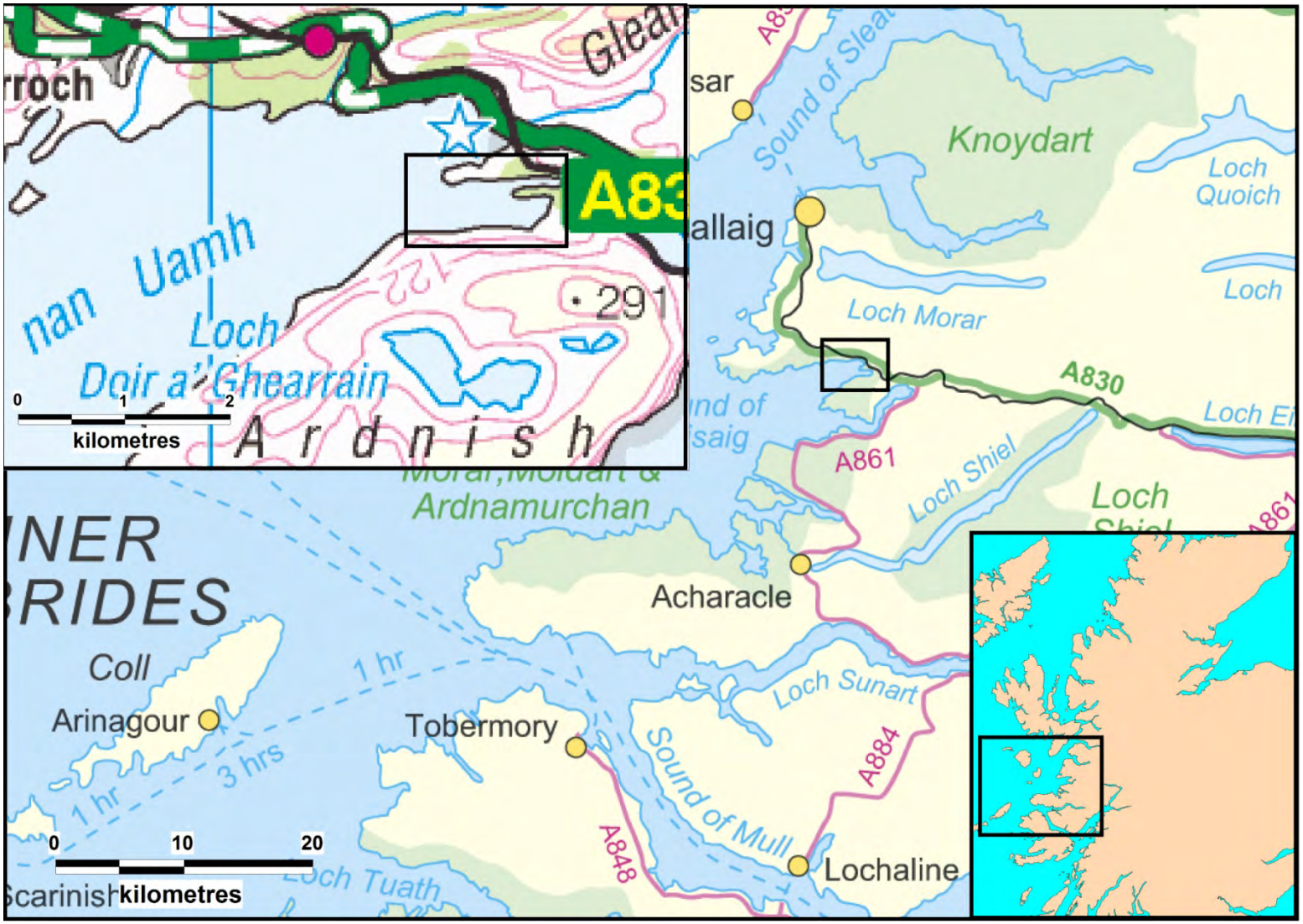


Figure 1.1 Location of Loch Beag

2. Fishery

Loch Beag is classified for the production of common mussels (*Mytilus edulis*), which are cultivated on long-lines.

Table 2.1 Production area details

Production area	Site	SIN	Species	RMP
Loch Beag	Ardnambuth	HL-118-215-08	Common mussels	NM 7260 8331

The production area covers the whole of Loch Beag with the boundaries defined as follows: the area bounded by lines drawn between NM 7223 8370 and NM 7200 8319 extending to MHWS.

The shoreline survey confirmed the presence of a single mussel farm site comprised of two long-lines approximately 300 m in length with 8 m droppers. The harvester identified that harvesting normally takes place year round. However, the harvester identified that issues with poor spat settlement had restricted the availability of harvestable stock.

The production area, current RMP location, and boundaries of the lines as recorded during the shoreline survey are shown in Figure 2.1.

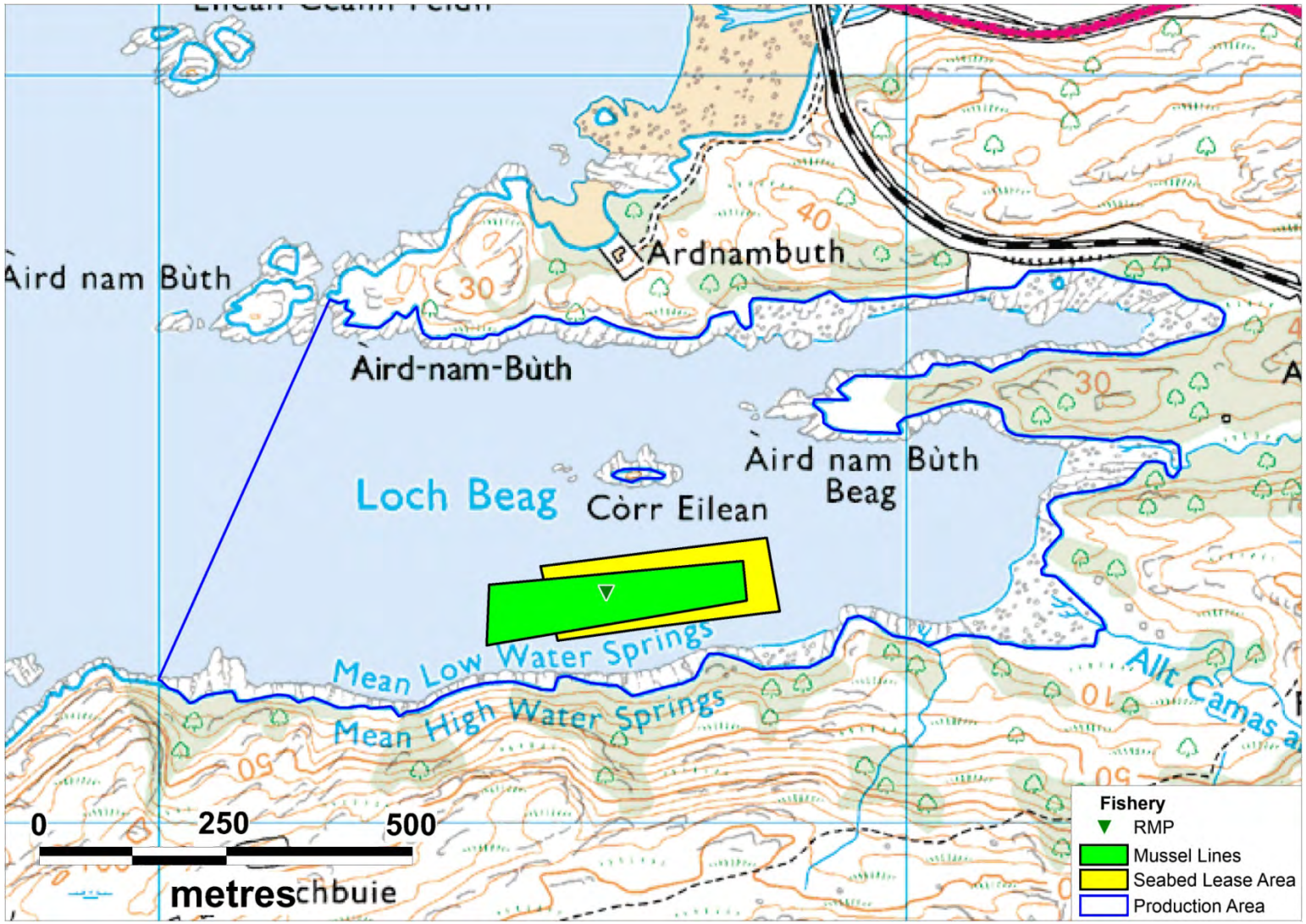


Figure.1 Loch Beag Fishery

3. Human Population

Information was obtained from the General Register Office for Scotland on the population within the vicinity of the Loch Beag production area. The last census was undertaken in 2011. The census output areas surrounding Loch Beag are shown thematically mapped by the 2011 population densities in Figure 3.1. The census output area adjacent to the fishery has a low population density (<3 people per km^2).

Table 3.1 Census output areas and populations – surrounding Loch Beag

Census Output Area	Population
S00081060	93
S00080981	52

The shoreline directly adjacent to the shellfish farm is largely inaccessible and uninhabited. A single dwelling is located at Ardnambuth, to the north of Loch Beag itself. Inland of the head of the loch are locations marked as Polnish and Arnipol: from aerial imagery these appear to be single dwellings rather than settlements (Google Maps; accessed 3/01/2014). The A830 and a train line run along the shore northeast of the loch. A number of houses lie along this road. Borrodale House, Arisaig House and Leven House all offer tourist accommodation (http://www.lhhscotland.com/properties/detail/?id=930, http://www.arisaighouse.co.uk/, http://www.thelevenhouse.co.uk/). In addition, the old station building at Beasdale Station appears to have been converted into a private dwelling that may be used as seasonal accommodation. It has been fenced off from the platform: at the time the Google™ earth street view image was taken, it did not appear to be occupied. During the shoreline survey a static caravan was observed on a grassy area west of Glen Mamie Farm and a wooden cabin or chalet was observed adjacent to Arnabol Burn, east of the shellfish farm.

There are three anchorages identified in the bay north of Àird-nam-bùth (Clyde Cruising Club, 2007). No boats were observed in the water during the shoreline survey. Overall, impacts from human sources to the water quality at the mussel farm are likely to be minimal due to the low population density of the area. There is likely to be significant seasonal variation in the area population due to the proportion of holiday accommodation. Any impact from visiting boats to the anchorages in the bay north of Loch Beag would be most likely to affect the northernwestern side of the shellfish farm.

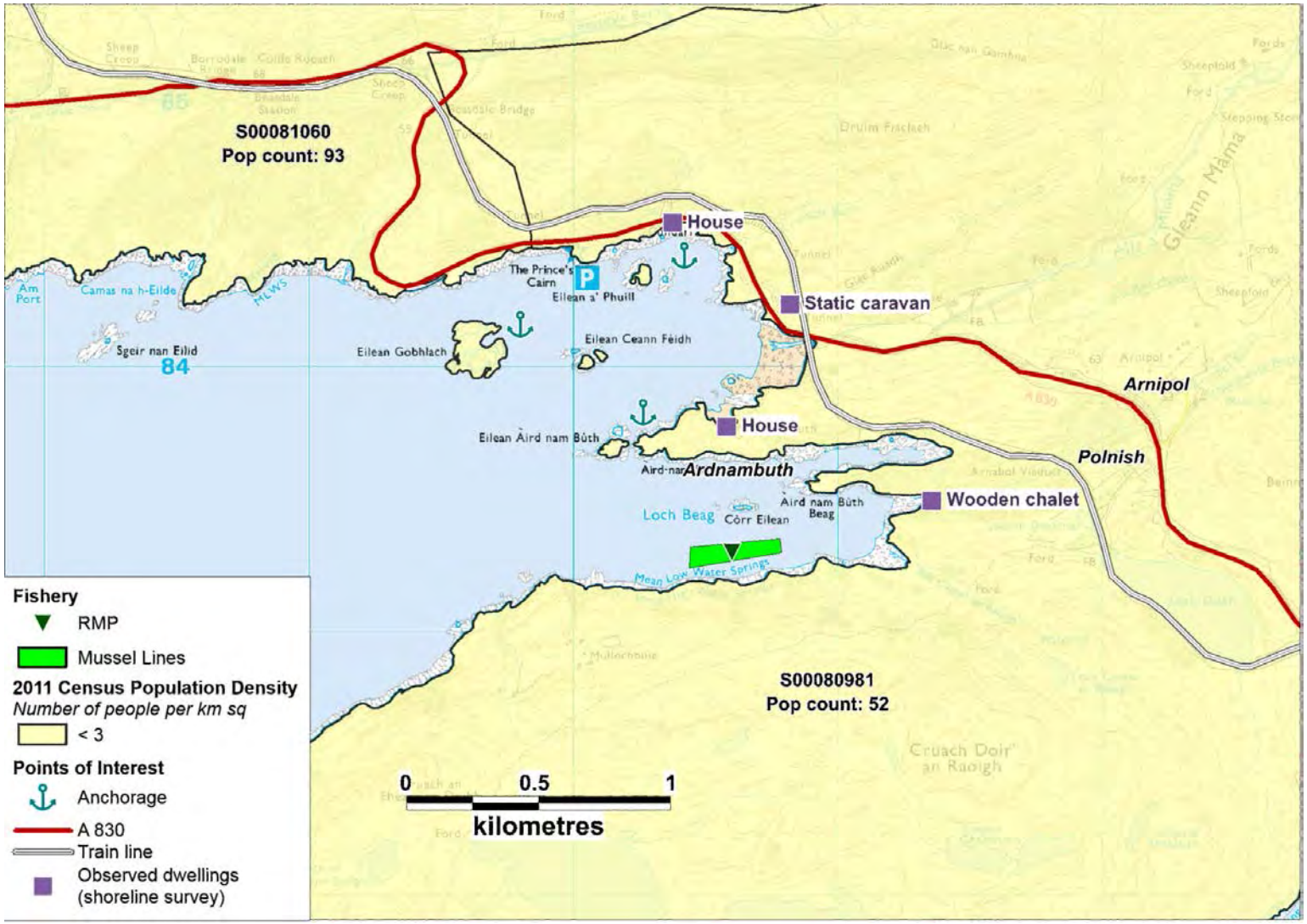


Figure 3.1 Population map for the vicinity of Loch Beag

4. Sewage Discharges

Information on sewage discharges within an area 7.5 km around the point NM 7300 8200, located on the Ardnish peninsula, 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.

4.1 Community Discharges

Scottish Water reported one septic tank within the area requested. No licence details were provided for this asset. Two location references were given for this septic tank; one relating to the location of the septic tank itself and the other relating to the outfall. Both were given to the nearest 100 metres, and both plot near road cuttings along the A830 west of Beasdale station. The nearest human development is a series of three attached cottages on the north side of the road. Signage visible from the A830 suggests that the septic tank lies directly opposite the cottages. It is considered likely that this tank services the cottages and discharges either to land or to the Allt na Glaic Mòire, which runs along the south side of the road.

No information was provided on sanitary or bacteriological quality or any planned changes in the area. No corresponding consent information was provided by SEPA for this septic tank.

The information provided by Scottish Water for this septic tank is given in Table 4.1 and its estimated location shown in Figure 4.1

Table 4.1 Community discharges around Loch Beag

Provider	Licence number	Location	Discharge Name	Type	PE	Discharges to
Scottish Water	-	NM 703 850 (outfall) NM 700 850 (tank)	BEASDALE SEP 1955	Septic Tank	-	-

PE = Population Equivalent, - = No data provided

4.2 Consented Private Discharges – SEPA

SEPA provided information regarding consented private discharges within the request area identified. Of these, only five discharges were within the catchment for Loch nan Uamh and Loch Beag. The remaining consented discharges were excluded from assessment because they were located outwith that area.

Details for the five consented discharges are summarized in Table 4.2 and their reported locations are given in Figure 4.1.

Table 4.2 SEPA consented discharges around Loch Beag

Licence number	Location	Discharge Name	Type	PE	Discharges to
CAR/R/1080985	NM 69432 85013	Dwelling, Arisaig	Sewage (Private) Primary	6	Borrodale Burn
CAR/R/1083141	NM 69250 84900	Dwelling, Arisaig	Sewage (Private) Primary	6	Soakaway
CAR/R/1095472	NM 69511 85127	Dwelling, Arisaig, Inverness-shire	Sewage (Private) Primary	6	Borrodale Burn
CAR/R/1100854	NM 68780 84990	2 Dwellings, Arisaig	Sewage (Private) Primary	11	Soakaway
CAR/R/1110362	NM 70710 85160	Beasdale Station*	Sewage (Private) Primary	5	Soakaway

* This appears to be a private dwelling rather than a station.

SEPA reported two discharges to Borrodale Burn. This burn flows into Loch Beag approximately 3.5 km northwest of the mussel lines.

Three of the consents were for discharges 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 have been diverted to sea or watercourses upon failure of the soakaway fields.

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

Shoreline Survey Discharge Observations

Three observations of sewage infrastructure were noted during the shoreline survey. These are listed in Table 4.3.

Table 4.3 Discharge-associated observations made during the shoreline survey

No.	NGR	Associated Photograph (Appendix 5)	Sample *E. coli* Value (cfu/100 ml)	Description
1	NM 72570 83805	Figure 3	4	Planned seawater sample in front of house next to pipe.
2	NM 72572 83806	Figure 3		Pipe running into sea from house behind. Cannot see if discharging or not as covered by sea.
3	NM 72583 83778			Ardnambuth House. Concrete structure with pipe end but no discharge.

Several dwellings were recorded along the shoreline survey route, however signs of sewage infrastructure were only observed at one dwelling.

All three recorded observations relate to a potential septic tank associated with a dwelling on the north side of the Àird-nam-bùth peninsula (i.e. outside of Loch Beag itself). A water sample taken from adjacent to the presumed septic tank outfall pipe returned a low value of 4 *E. coli* cfu/100 ml.

Several dwellings for which no sewage infrastructure was noted were observed during the shoreline survey. All of these are likely to have associated sewage discharges in some form. All three are situated close to watercourses and therefore any septic discharges may impact these.

Details of these observations and associated samples are given in Table 4.4.

Table 4.4 Observed dwellings made during the shoreline survey

No.	NGR	Associated Photograph (Appendix 5)	Sample *E. coli* Value (*E. coli* cfu/100 ml)	Description
D1	NM 72378 84548	Figure 7	270	Three buoys and a small storage platform on water in front of house.
D2	NM 72821 84242	Figure 5	10	One static caravan with one occupant on grassland next to burn.
D3	NM 73358 83498	Figure 9	<10	Small watercourse (Arnabol Burn) running down glen past wooden chalet onto shore.

The water samples taken from watercourses near these dwellings returned low values indicating little faecal contamination at the time of survey. It is possible that samples were taken above the point of any faecal input.

Dwelling 3 (D3) is located at the head of Loch Beag approximately 600 m from the edge of the fishery. The other discharges are over 1 km from the fishery on the opposite side of the Àird-nam-bùth peninsula.

Summary

As the area around Loch Beag is sparsely inhabited, potential sources of human faecal pollution are limited to small private discharges in the main. SEPA reported consents for four private sewage discharges with PEs ranging from 5 - 11 located on the north coast of Loch nan Uamh. Two of these discharge to Borrodale Burn, with the remaining three discharging to soakaway. There are highly likely to be additional discharges from homes along the A830 north of Loch nan Uamh.

One community discharge is recorded west of Beasdale Station. This is likely to serve a trio of cottages on the north side of the road, and may discharge near or to Allt na Glaic Mòire.

The shoreline survey report observed several dwellings. All of these are assumed to discharge sewage effluent to some degree, given the lack of community sewage treatment, however evidence of sewage infrastructure was reported at only one, on the north shore of the Àird-nam-bùth peninsula. A seawater sample taken from near the end of this discharge pipe indicates a low level of contamination.

The nearest potential source of faecal contamination to the fishery discharges approximately 600m from it, although the actual risk posed is unknown. The nearest known discharge is over 1 km from the fishery, on the other side of the Àird-nam-bùth peninsula.

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

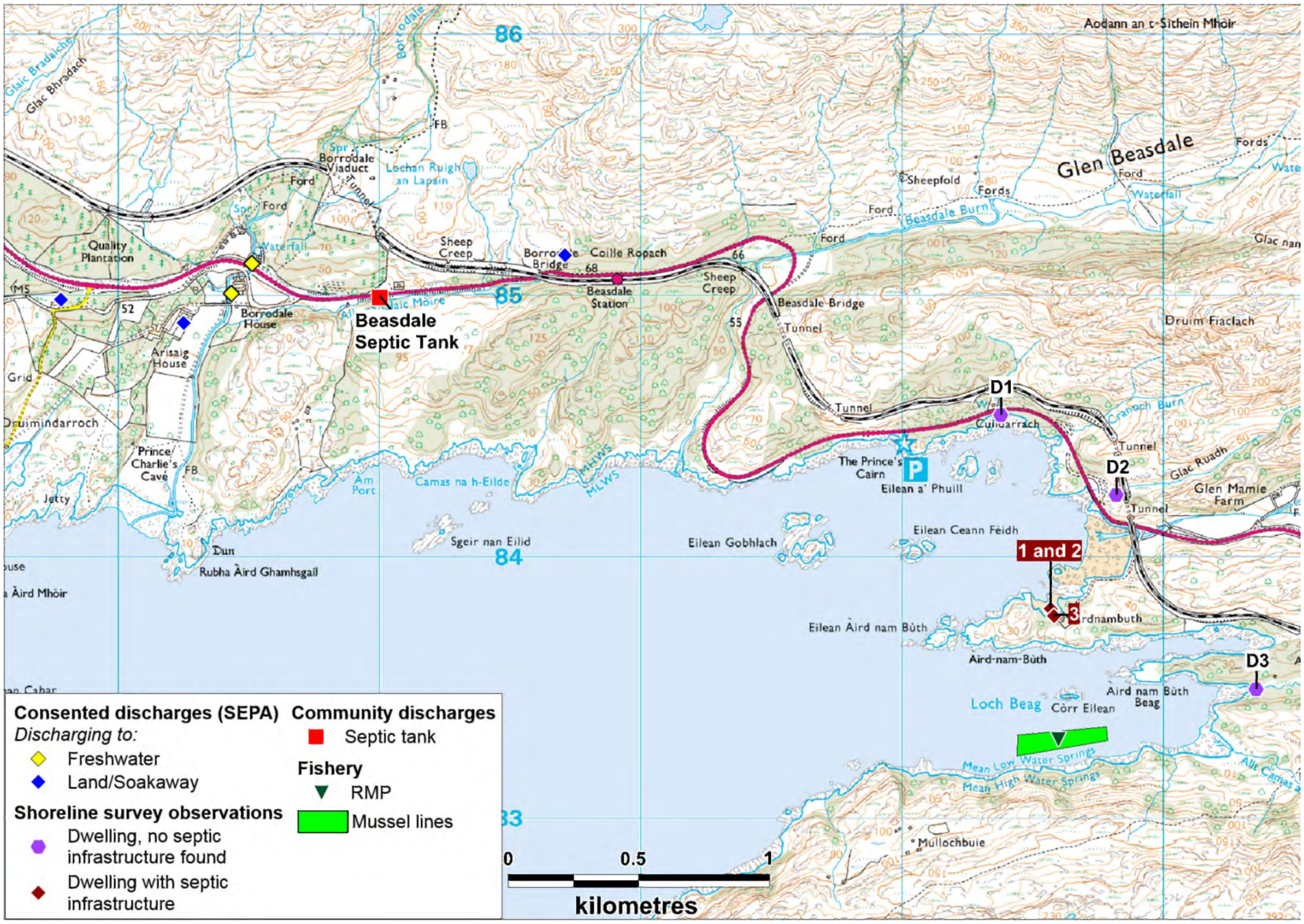


Figure 4.1 Map of discharges for Loch Beag

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. Parish level agricultural census data was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for the Arisaig and Moidart 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 Arisaig and Moidart agricultural parish 2013

	Arisaig and Moidart	
	465 km^2	
	Holdings	Numbers
Pigs	*	*
Poultry	*	*
Cattle	23	796
Sheep	23	3,185
Horses used in Agriculture	0	-
Other horses and ponies	13	38

* data withheld

The livestock census numbers for Arisaig and Moidart relate to a very large parish area, therefore it is not possible to determine the spatial distribution of the livestock on the shoreline adjacent to the loch or to identify how many animals are likely to impact the catchment around the mussel farm. Although the figures are of little use in assessing the potential impact of livestock contamination to the shellfishery, they do give an idea of the total numbers of livestock over the broader area. Sheep were most numerous, but in lower numbers than were reported from many other rural parishes in Scotland. Cattle were the next numerous with small numbers of horses and ponies. No pig or poultry numbers were reported for the parish due the small number of holdings.

A potential source of spatially relevant information on livestock population in the area is the shoreline survey (see Appendix 5). Observations made during the site visit on the 16th and 17th June 2014 are specific only to those dates and do not address variation in animal numbers over time. All survey observations are dependent upon the viewpoint of the observer, and some animals may have been obscured by the terrain. No livestock or signs of agricultural activity were noted during the shoreline survey.

Review of publicly available aerial images shows areas of improved pasture or grass located around Glen Mamie Farm, northeast of the mussel farm, and at Arisaig House, on the north shore of Loch nan Uamh northwest of the mussel farm (Image date April

2012, http://mvexel.dev.openstreetmap.org/bing/). Livestock were clearly visible in the aerial images. Six sheep were visible on grassland at Glen Mamie Farm and 62 were visible on pasture south of Arisaig House. At Glen Mamie Farm, the Allt a' Mhàma flows through the pasture area and at Arisiag House the Borrodale Burn flows along the east side of the pasture area. At both farms, sheep appeared to be kept away from the shoreline by fences. Areas identified from the aerial images as likely improved pasture are shown in Figure 5.1. Those on which livestock were visible are marked with a "+".

Numbers of sheep are expected to be approximately double during the spring and summer months when lambs are present. Any contributions of faecal contamination from livestock are expected to be low, however livestock grazing on the improved pasture at Glen Mamie Farm could potentially affect the northwestern side of the longlines, depending on current patterns and particle transport distances.

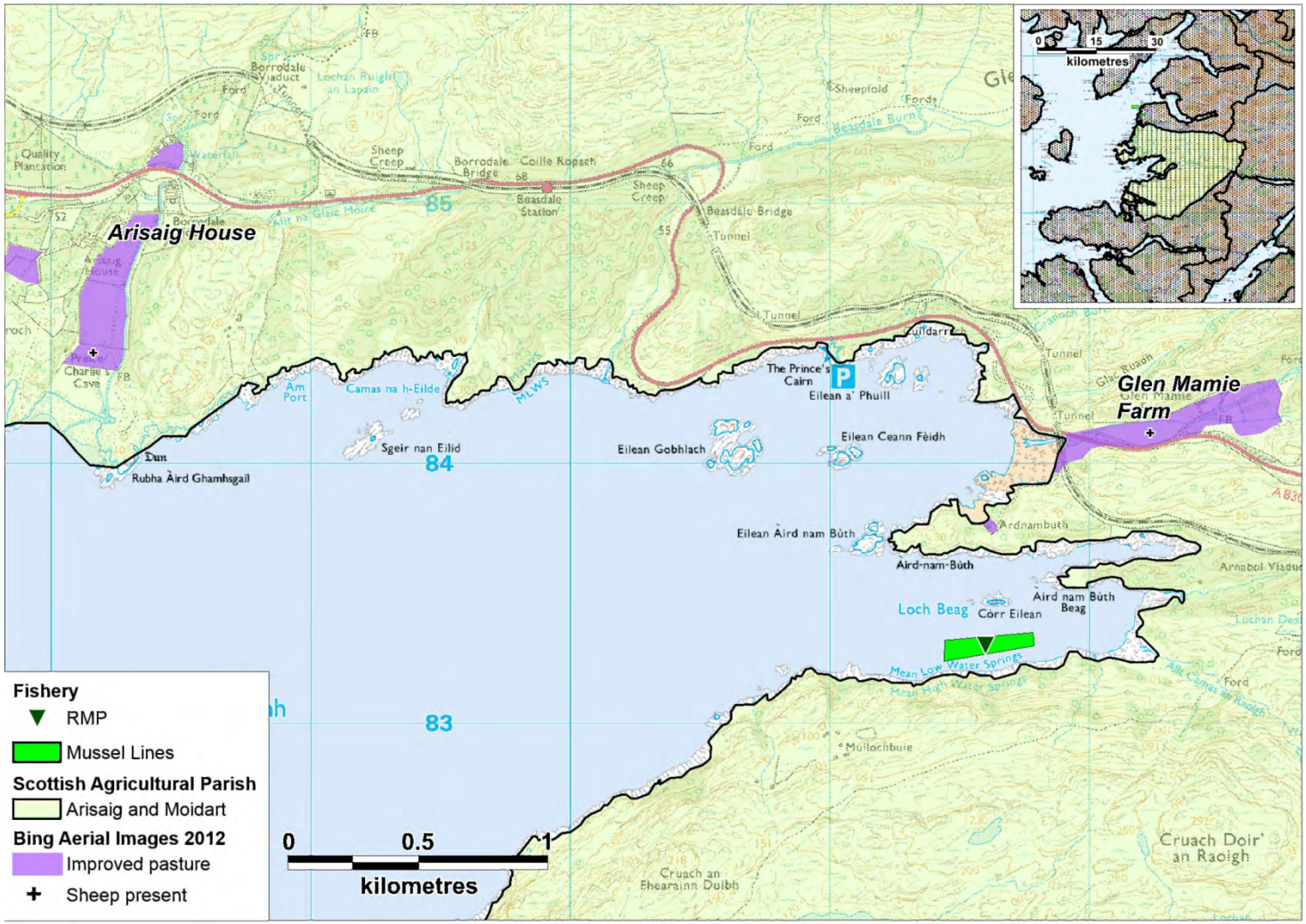


Figure 5.1 Livestock observations at Loch Beag

6. Wildlife

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

The species for which information was likely to be available and which, if present, could contribute to faecal indicator levels around the mussel fishery at Loch Beag, are considered below.

Pinnipeds

The Special Committee on Seals Report (Special Committee on Seals, 2013) indicated that there were approximately 50 common seals (*Phoca vitulina*) observed around Loch Beag in the month of August between the years 2007 and 2011 with more (approximately 500) being reported seaward of this location. It should be noted that the counts relate to 10 km squares. No change in numbers of seals observed between 2008 and 2012 has been reported for the West coast of Scotland including the Outer Hebrides. Comparatively few grey seals (*Halichoerus grypus*) have been noted in the area, with only five observed over the same time period. No seals were observed during the shoreline survey.

Cetaceans

There are no reports of cetaceans within Loch Beag and none were seen 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 show the most recent data where repetitions of counts were present. It should be appreciated that the sources of this data are varied, with some recorded as unknown or estimated, whilst some come from reliable detailed surveys such as those carried out for the Seabird 2000 report by Mitchell *et al.*, (2004). Data applicable for the 5 km area around the fishery are listed in Table 6.1.

Table 6.1 Seabird counts within 5 km of Loch Beag

Common name	Species name	Count*	Method
Great Black-Backed Gull	Larus marinus	10	Occupied nests and territory
Herring Gull	Larus argentatus	20	Occupied nests
Black-Headed Gull	Chroicocephalus ridibundus	2	Occupied nests
Common Gull	Larus canus	40	Occupied nests
Arctic Tern	Sterna paradisaea	2	Occupied territory
Common Tern	Sterna hirundo	274	Occupied nests and territory
Shag	Phalacrocorax aristotelis	12	Occupied nests

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

The JNCC dataset indicated common terns were abundant in the surrounding areas to Loch Beag. A large nesting colony was located approximately 2.8 km southeast of the Loch Beag fishery in Loch Ailort, with a second moderately sized colony situated approximately 840 m northwest on Eilean Ceann Feidh. Small nesting colonies of great black-backed gulls, herring gulls, common gulls and shags were also noted.

Common terns are reported to feed predominantly within 3–10 km of the colony, whilst greater distances of up to 37 km have been reported (Cramp, et al., 1974). It is therefore expected that they will use the Loch Beag area at times to feed/rest, particularly during their main breeding season between May and August (Birds in Backyards, 2014).

During the shoreline survey, birds were the only wildlife noted, with species including oystercatchers, gulls and eider ducks observed north of the fishery. The JNCC seabird data and the shoreline survey observations are summarized in Figure 6.1.

Otters

There are no specific datasets referring to Eurasian otters (*Lutra lutra*) in Loch Beag. However, there is anecdotal evidence to suggest that the area is home to otters, which are noted to be present around the old ferry house (Scottish Anchorages, 2014).

Overall

The most significant wildlife source of contamination is expected to be common seals present in the area, though this may vary to some extent temporally. Seabirds, in particular common terns, are also anticipated contribute contamination source to the fishery, however the nesting colonies are some distance away from the mussel farm and any impacts are expected to be mainly restricted to the breeding season.

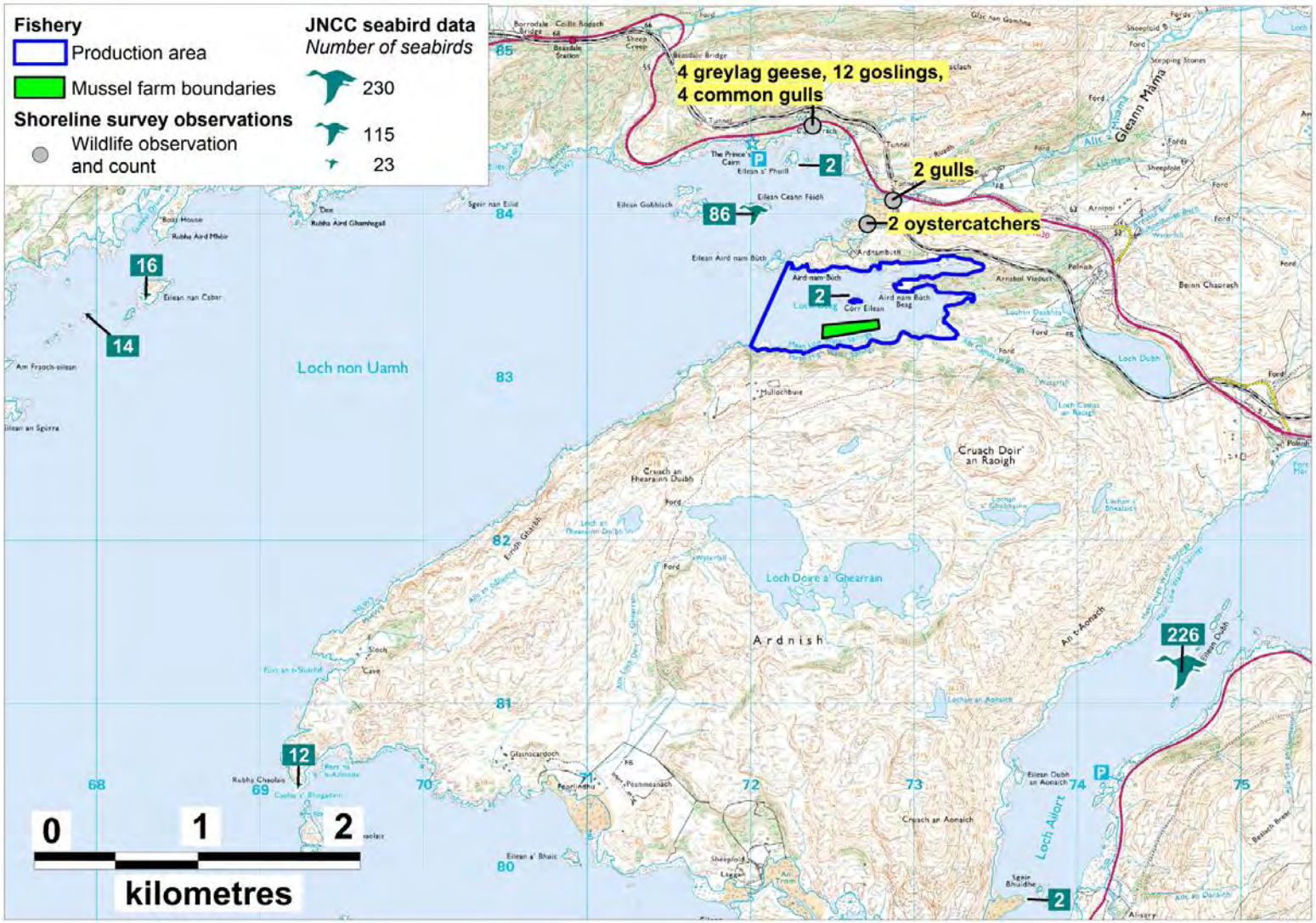


Figure 6.1 Map of wildlife around Loch Beag

7. Land Cover

The Land Cover Map 2007 data for the area is shown in Figure 7.1. There are no built up or urban areas represented in the data for the area. The predominant land cover types adjacent to Loch Beag are broad leaved woodland, rough grassland, dwarf shrub heath, coniferous woodland and improved grassland. There are also scattered small areas of acid grassland. A small area to the southwest of the mussel farm identified as being arable and horticultural land actually appears to be a steep hillside with trees and/or scrub and no access and therefore is considered likely to be classified in error. The shorelines north and south of the mussel lines are composed of broad leaved woodland. The improved grassland identified on Àird nam Bùth Beag, to the northeast of the mussel farm appears to be woodland/scrubland in aerial images and therefore is also considered to be in error.

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., 2008b). 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., 2008a).

The highest potential contribution of contaminated run-off to the Loch Beag mussel farm is from the areas of improved grassland located to the northeast and outside Loch Beag. Therefore, this is not expected to have a significant impact on contamination levels at the shellfish farm.

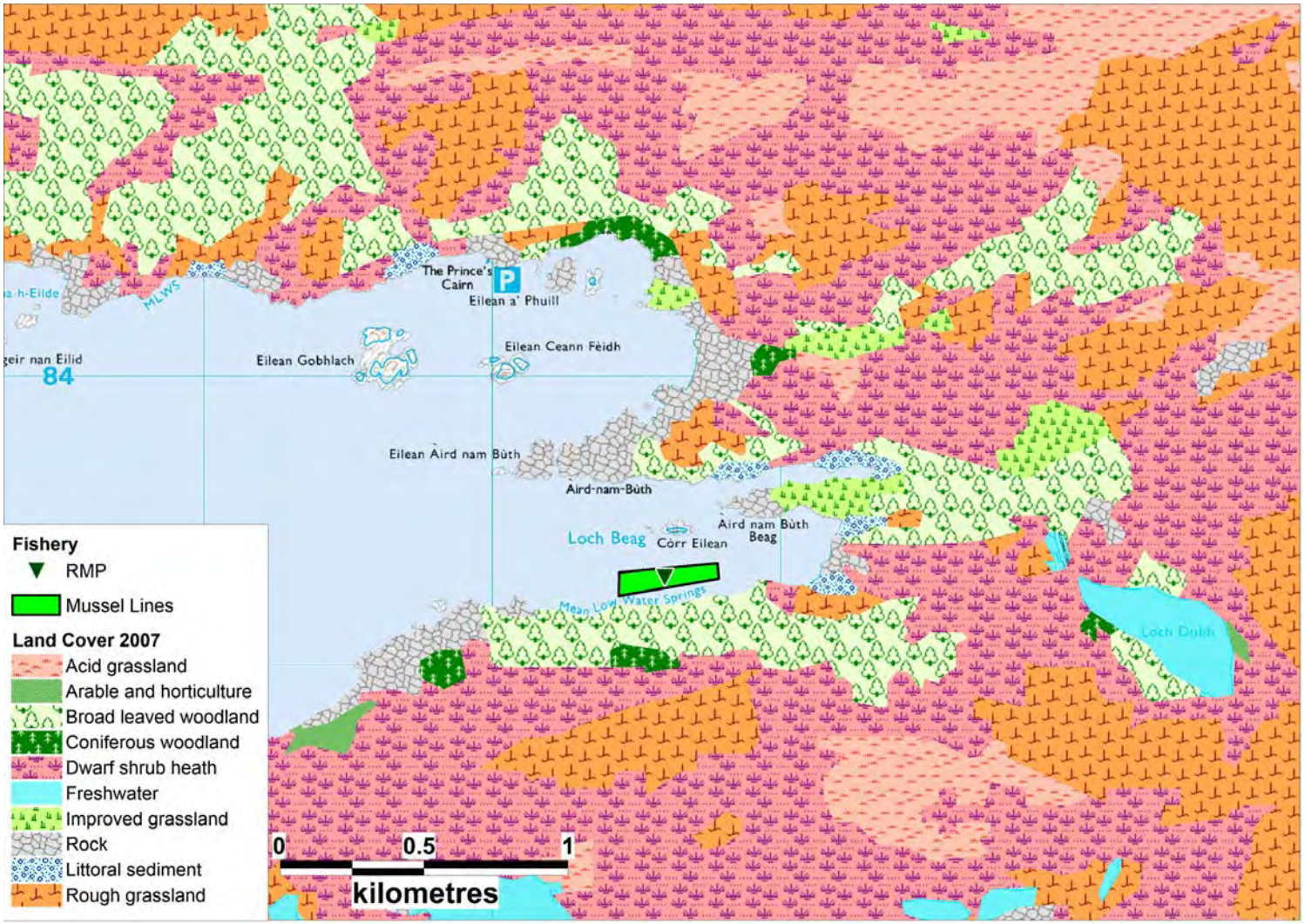


Figure 7.1 LCM2007 land cover data for the area around Loch Beag

8. Watercourses

There are no gauging stations on watercourses entering Loch Beag.

Spot measurements of flow and microbial content were obtained during the shoreline survey conducted on the 16th June 2014. No precipitation was recorded in the 48 hours prior to the survey. The watercourses listed in Table 8.1 are those recorded during the shoreline survey. No areas of land drainage were observed. The locations and loadings of measured watercourses are shown in Figure 8.1.

Table 8.1 Watercourses entering Loch Beag

No.	Eastings	Northings	Description	Width (m)	Depth (m)	Flow (m^3/d)	Loading (*E. coli* per day)
1	172873	784089	Allt a' Mhàma	5.57	0.22*	18800	7.5×10^9
2	172822	784242	Glac Ruadh	1.1	0.09	992	9.9×10^7
3	172753	784301	Unnamed watercourse	0.72	0.07	105	2.1×10^7
4	172666	784483	Cranoch Burn	1.45	0.06	819	$<8.2 \times 10^{7**}$
5	173037	783243	Unnamed watercourse	1.17	0.13	1040	$<1.0 \times 10^{8**}$
6	173209	783281	Allt Camas an Raoigh	0.82	0.08	244	$<2.4 \times 10^{7**}$
7	173358	783498	Arnabol Burn	2.51	0.15	1460	$<1.5 \times 10^{8**}$

* 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.

Allt a' Mhàma (watercourse No. 1) had a moderate estimated *E. coli* loading while the others either had low loadings or the loading could not be determined due to the *E. coli* result being less than the lower limit of detection. However, this watercourse, plus watercourses 2 to 4, are located north of the Àird-nam-bùth peninsula and are not likely to have a significant impact at the site of the present fishery. Watercourses No. 5 to 7 lie within 600 m of the eastern end of the mussel farm. The *E. coli* loading of all of the watercourses would be expected increase after heavy rainfall and, under those conditions, watercourses 5 to 7 could impact on the water quality at the eastern end of the mussel farm.

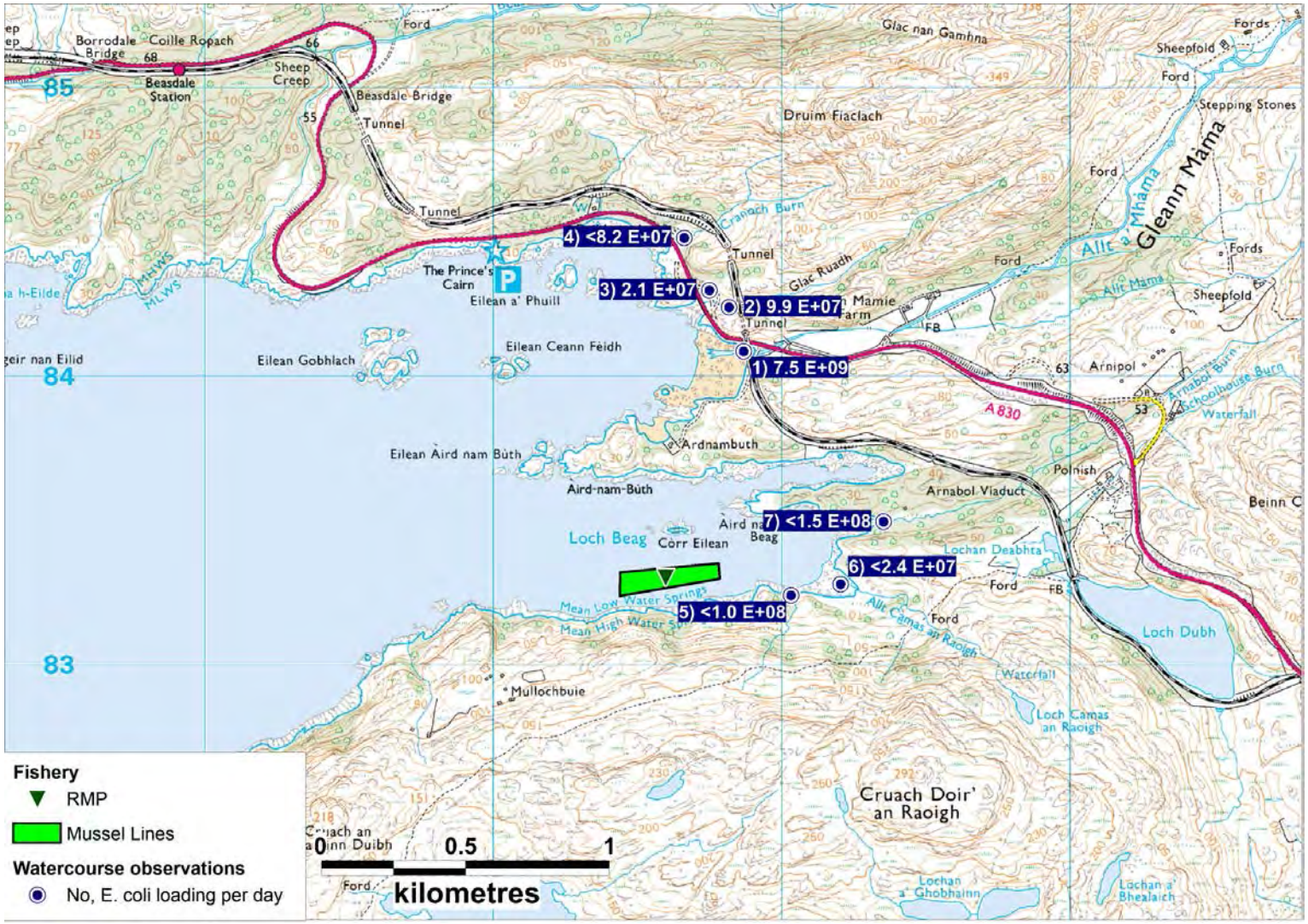


Figure 8.1 Map of watercourse loadings at Loch Beag

9. Meteorological Data

The nearest weather station for which a nearly complete rainfall data set was available is located at Inverailort, situated approximately 5 km to the southeast of the production area. Rainfall data was available for January 2008 – December 2013. Rainfall data was missing for 4 months in 2010 (April, October, November, and December) and for October 2011.

The nearest wind station is situated in Tiree, located 80 km south west of the production area. Conditions may differ between this station and the fisheries due to the distances between them. However, this data is still presented 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 Beag.

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 *.

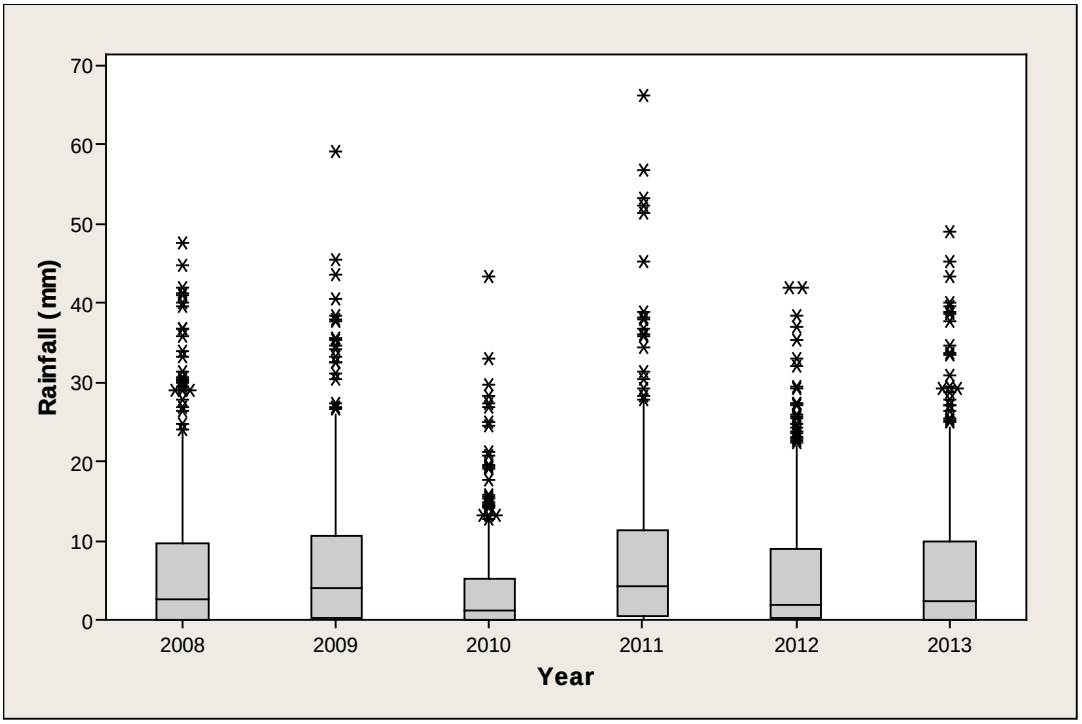


Figure 9.1 Box plot of daily rainfall values by year at Inverailort (2008 – 2013)

Total rainfall varied from year to year, with 2010 being the driest year (1083 mm). The wettest year was 2011 (2745 mm). Rainfall values exceeding 50 mm/d occurred once in 2009 and five times in 2011. Rainfall exceeding 60 mm/d occurred on one occasion in 2011. It should be noted that data was missing for a three-month period between October and December of 2010. This year was recorded as the year with the lowest rainfall, both on average and overall. However, as these months typically show above average rainfall, the actual total rainfall value will have been markedly greater. Data was also missing for April 2010 and October 2011. This will also reduce the respective annual and monthly rainfall totals.

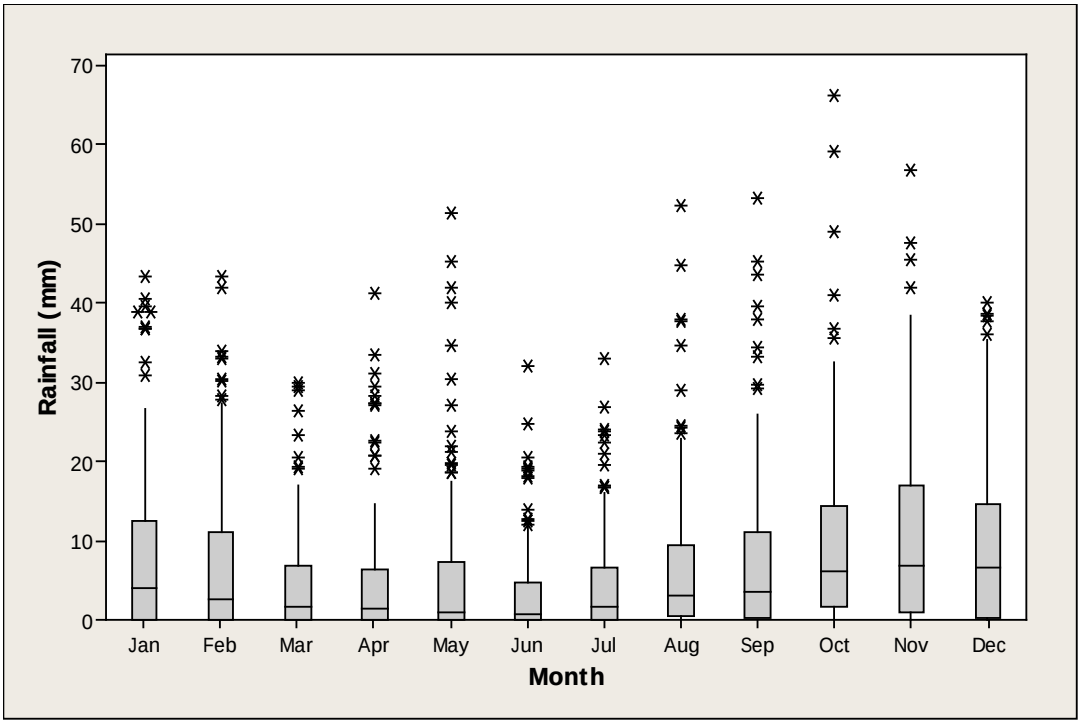


Figure 9.2 Box plot of daily rainfall values by month at Inverailort (2008 – 2013)

Daily rainfall values were higher during the autumn and winter. Total monthly rainfall over the period was greatest in November (2065 mm) and least in June (592 mm). Rainfall values exceeding 50 mm/d occurred in May, August, September, October and November. The rainfall event exceeding 60 mm/d occurred in October.

For the period considered here (2008 – 2013), 39 % of days received daily rainfall of less than 1 mm and 24 % 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 Tiree and summarised in seasonal wind roses in Figure 9.3 and annually in Figure 9.4.

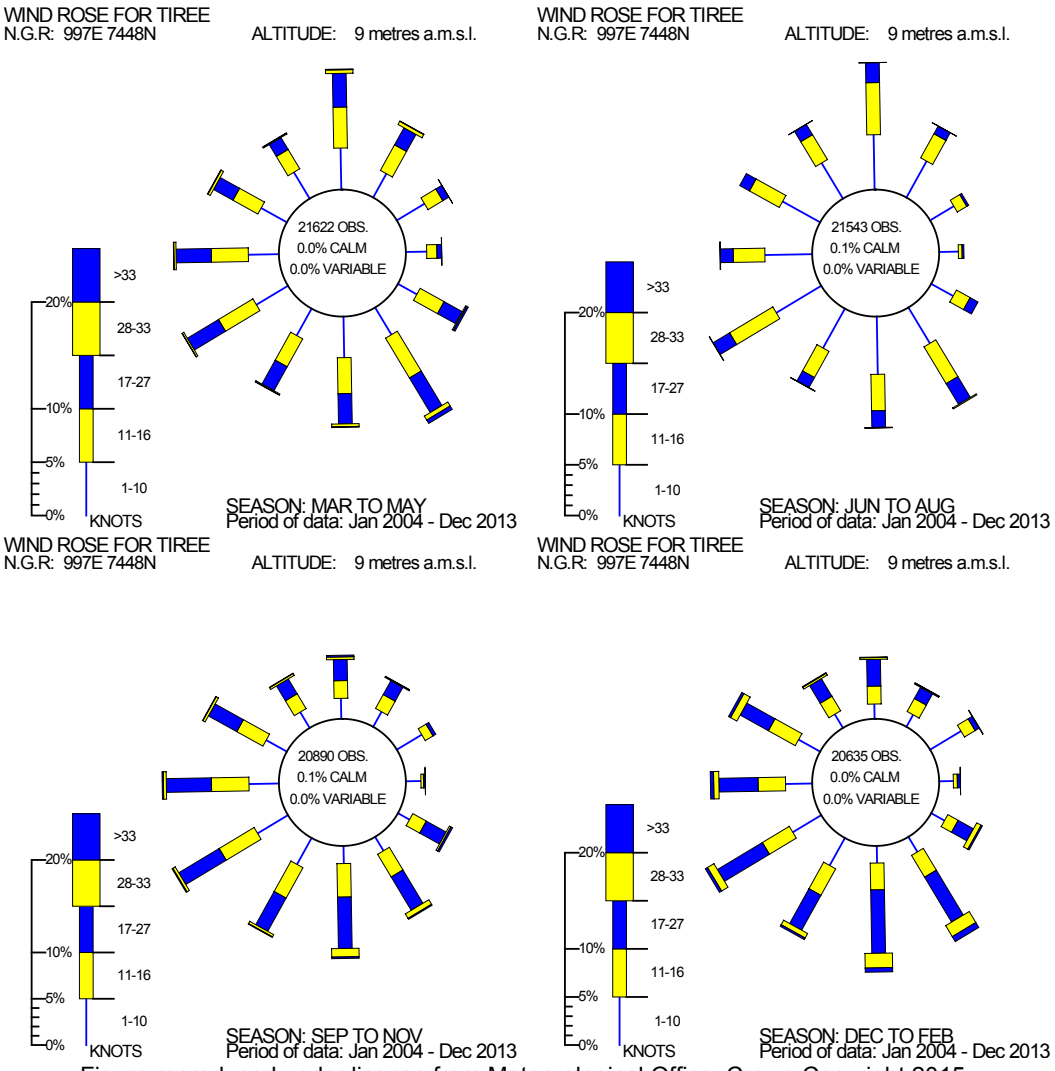


Figure 9.3 Seasonal wind roses for Tiree

Overall, the winds predominantly came from between south- southeast and west with the strongest winds being those from the south. There was also a lesser, but significant, proportion of northerly winds. Seasonally the strongest winds occurred during the autumn and winter. The northerly winds occur mainly in the spring and summer.

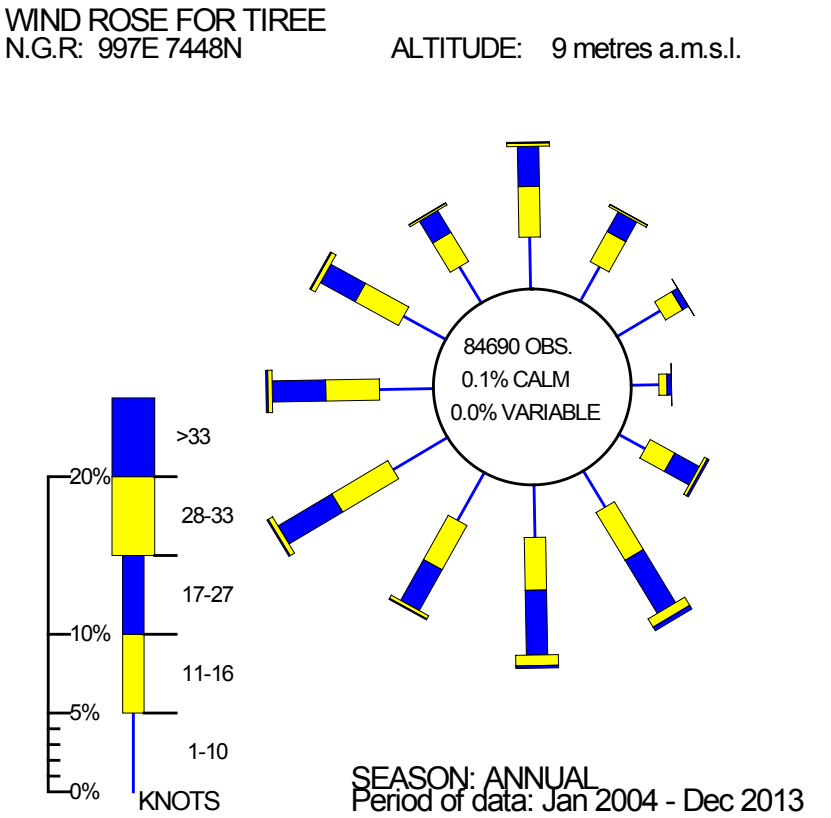


Figure 9.4 Annual wind rose for Tiree

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 Beag is classified for production of common mussels (*Mytilus edulis*). The classification history since 2006 is listed in Table 10.1.

Table 10.1 Loch Beag: (common mussel) classification history

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

Since 2009, the area has been given a year-round A classification.

11. Hydrography

11.1 Introduction

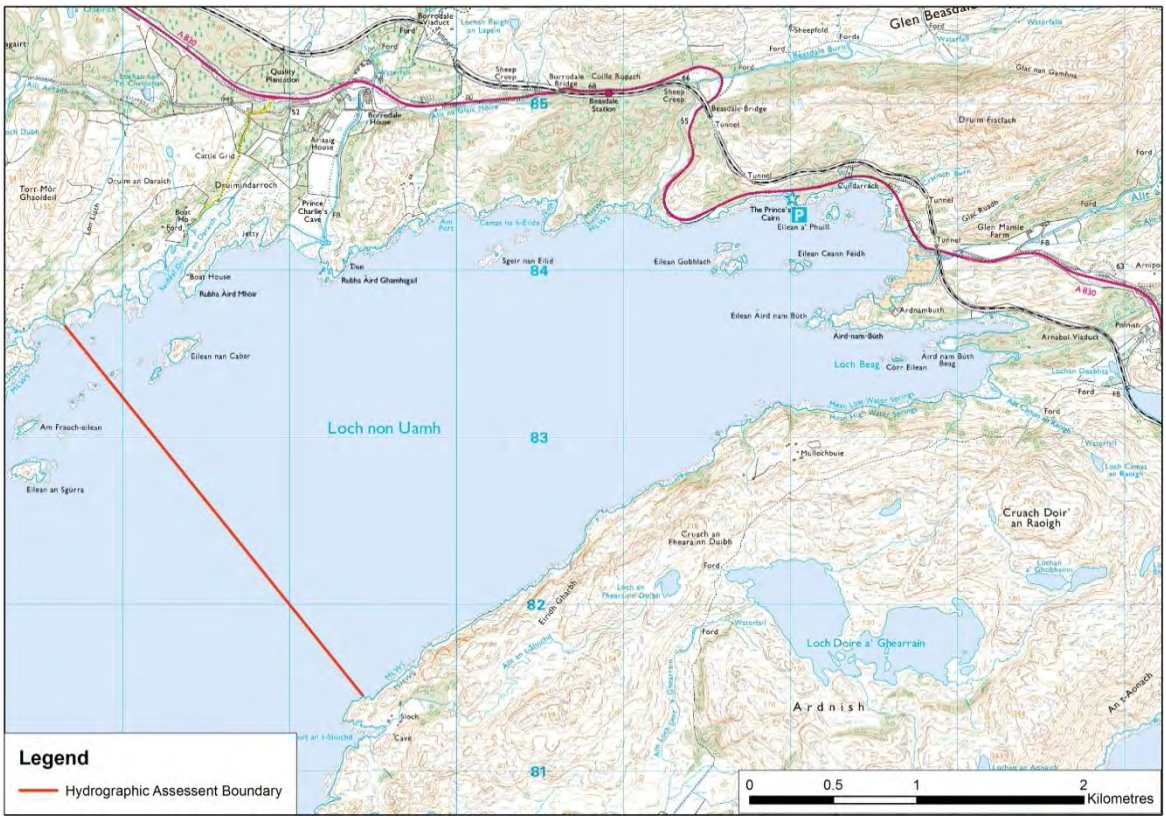
11.1.1 The Study Area

Loch Beag is situated in the Highland region on the west coast of Scotland. Loch Beag itself is a subsidiary loch to the larger Loch Nan Uamh, both of which are found within the assessment area, as shown in Figure 13.1. Loch Beag joins Loch Nan Uamh at the point Àird-nam-Bùth. The assessment area is demarcated by the red line in Figure 13.1, and encompasses all of Loch Nan Uamh to the east of Port an t-Sluichd in the south and to the east of An Garbh Eilean in the north.

The assessment area lies within a sparsely populated region, away from industrial activities and agriculture. The lochs are bordered on the north side by the A830 road and a railway line, with a railway station found at Beasdale. One village, Druimndarroch, borders Loch Nan Uamh on the northern side, while a small settlement, Polnish, is found to the east of the assessment area.

At its mouth, Loch Nan Uamh joins the Sound of Arisaig. The landscape around the loch is characterised by low hills and on the south side of the assessment area, by several freshwater lochs, including Loch Doire a Ghearrain. Numerous small streams and burns flow into Loch Nan Uamh and Loch Beag, including Allt a' Mhàma Borrodale Burn and Beasdale Burn.

The total length of Loch Nan Uamh is 4.3 km, while Loch Beag is 1.2 km in length. Loch Nan Uamh is widest at the western edge of the assessment area, at 2.8 km in width, and narrows to approximately 0.76 km at its head. Loch Beag is fairly consistent in width, at approximately 0.5 km.



Produced by Cefas Weymouth Laboratory. © Crown Copyright and Database 2015. All rights reserved. Ordnance Survey licence number [GD100035675]

Figure 11.1 Extent of the hydrographic study area

The Sound of Airsaig marine Special Area of Conservation (SAC) is found immediately to the south of the assessment area. This area is designated as a SAC for the habitat 'Sandbanks which are slightly covered by sea water all the time', which is listed on Annex I of the EU Habitats Directive (Scottish Natural Heritage, 2006). Loch nan Uamh has also been cited as notable for the wide range of intertidal communities occurring along its shores, and for the most northerly known occurrence of the green alga *Codium adhaerens* (Connor & Little, 1998).

Coordinates for Loch Beag:

56.883674 °N 005.774110 °W
OSGB36 National Grid 170173.98 783270.974

11.2 Bathymetry and Hydrodynamics

11.2.1 Bathymetry

Figure 13.2 shows the bathymetry of the assessment area. There are no sills in the loch that would significantly hinder the exchange of water. Water depths are greatest along the Ardnish Peninsula at the southern side of the loch and generally become shallower towards the northern edge of Loch Nan Uamh. There is a shallow ridge extending diagonally along the middle of the Loch from the tidally exposed rocks at

Bogha Sgeir nan Eilid in the north, in a south westerly direction towards the assessment area boundary. This ridge becomes as shallow as 4.2 m just outside the boundary.

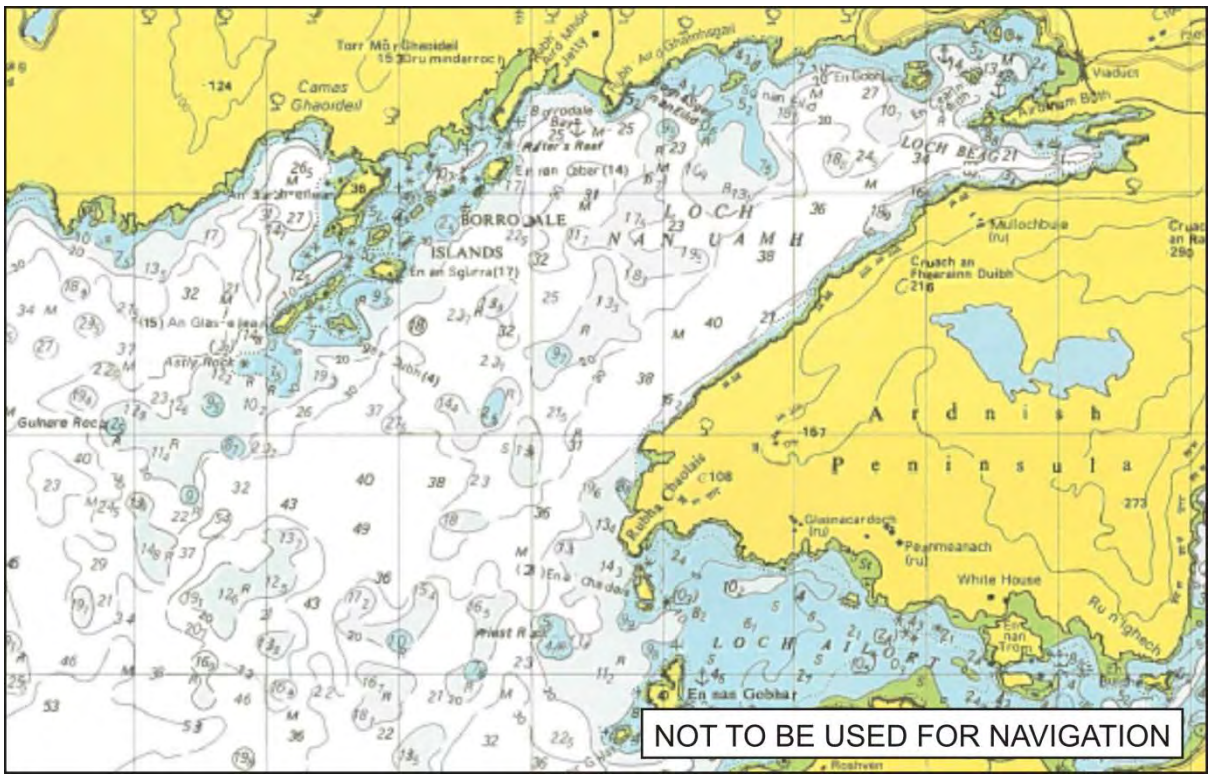


Figure 11.2 Admiralty chart (2207) extract for Loch Nan Uamh and Loch Beag. No relevant ADCP stations are available in the vicinity of the assessment area.

The depth of the assessment area varies substantially from 49 m at the southern extremity along the Ardnish Peninsula to 5 – 6 m along the northern boundary near Bogha Sgeir nan Eilid. Depths are more consistent along the southern and eastern boundaries of the assessment area, gently sloping from 49 m at Rubha Chaolais to 21 m in Loch Beag.

11.2.2 Tides

Data on tidal information is provided based on tidal characteristics determined from Mallaig. Mallaig is 15kms to the north northwest of Loch Beag.

Standard tidal data for Mallaig, centred around the survey date of 16th June 2014, are shown in Figure 13.3. Tidal predictions for Mallaig indicate that in this region the tidal characteristics are semi-diurnal, with a well-developed spring-neap cycle.

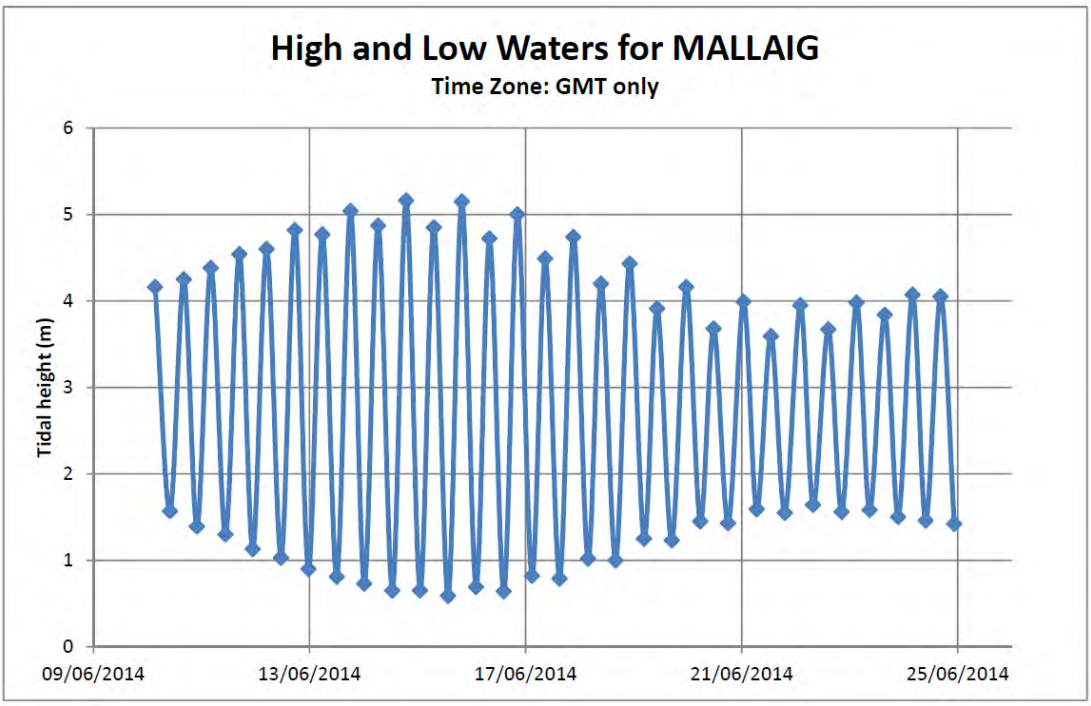


Figure 11.3 Two week tidal curve for Mallaig.
Reproduced from Poltips3 [www.pol.ac.uk/appl/poltips3]

Tidal heights in Mallaig, data from Poltips3 [www.pol.ac.uk/appl/poltips3]:

Mean High Water Springs = 5.0 m
Mean Low Water Springs = 0.8 m
Mean High Water Neaps = 3.6 m
Mean Low Water Neaps = 2.1 m

This gives an approximate tidal volume of water within the assessment area during each tidal cycle of:

Springs: 3.68×10^7 m^3
Neaps: 1.33×10^7 m^3

11.2.3 Tidal Streams and Currents

There are no published tidal diamonds for this area. There are no narrows or sills within the assessment area, though tidal streams may be slightly enhanced around small islands found along the northern edge of the assessment area and just outside the western boundary of the assessment area.

No relevant current meter data were available for the assessment area, and as such it is difficult to quantitatively assess tidal streams, current flows, and cumulative transport in Loch Beag and Loch Nan Uamh.

The bathymetry along the southern edge of Loch Nan Uamh and Loch Beag suggests that in the southern parts of the assessment area, currents may flow along a south west to north east axis, while the direction of flows may be more variable around the more complex bathymetry in the northern part of the assessment area. Current speeds will vary with spring and neap tides.

Given the tidal volume of water in the assessment area, over an average ebb period of 372 minutes (Poltips3 [www.pol.ac.uk/appl/poltips3]), it is possible to approximate average current flow speeds across the assessment area boundary being of the order 0.1 m/s.

Using the estimated average flow speed above and assuming a uniform sinusoidal tide, the cumulative transport that might be expected during each phase of the tide (approximately 6 hours) has been approximated as 1.3 km. It is important to note that this figure must be treated with caution, as it is not based on a quantitative current speed dataset.

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 nan Uamh or Loch Beag. Without such data it is difficult to judge what the dispersive environment might be like. However, the assessment area will be exposed to substantial wave energy in the form of longer period swells originating in the North Atlantic Ocean, and shorter period waves generated within the loch and adjacent Sound of Arisaig. This wave energy is likely to enhance dispersion of surface contaminants within the assessment area.

11.2.4 River/Freshwater Inflow

Three larger streams flow into Loch Nan Uamh: Allt a'Mhàma flows into the head of Loch Nan Uamh at its eastern end, while Beasdale Burn and Borrodale Burn flow into the northern boundary of the loch. Loch Beag is fed by Allt Camas an Raoigh at its eastern end. Several other lesser streams also flow into the assessment area along both northern and southern boundaries.

11.2.5 Meteorology

The nearest weather station for which a continuous rainfall dataset is available is located at Inverailort. This station is situated approximately 5 km to the southeast of the assessment area. Rainfall records are available from January 2008 to December 2013.

While 2010 generally was the driest year (1083 mm), the highest rainfall for this time period was recorded in 2011 (2745 mm). High rainfall values (> 40 mm d^{-1}) occurred in every year, but rainfall events of > 60 mm d^{-1} were recorded in 2009 and 2011. Rainfall events of > 30 mm d^{-1} occurred in all months, and high rainfall values of 60 mm/d were only seen in October. Daily rainfall varied seasonally, from lower values in the summer months (June and July) to higher values in the autumn months (September – November). Mean rainfall at Inverailort peaks in October, and during this month in 2011 a rainfall event of approximately 65 mm d^{-1} occurred. For the duration of the dataset, daily rainfall of below 1 mm occurred on 38% of days, while daily rainfall above 10 mm occurred on 24% of days.

Run-off due to rainfall is expected to be highest in the autumn 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. For the nearby Loch Ailort, the annual precipitation in the area is approximately 2000 mm (Edwards & Sharples, 1986) with considerable seasonal variability.

Wind data were obtained from Tiree Airport, located 80 km to the southwest 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 Beag. They are, however, valuable in providing the general pattern of the seasonal wind conditions. Data collected between January 2004 and December 2013 indicate that the predominant wind direction is between south southeast and west. There was also a lesser, but significant, proportion of northerly winds. Seasonally the strongest winds occurred during the autumn and winter. Typically the wind came from around the south and west throughout the year but the summer also saw winds from the northeast. The northerly winds occur mainly in the spring and summer. Local wind directions in Loch Beag are likely to be somewhat influenced by the surrounding topography.

11.2.6 Model Assessment

Due to the paucity of data for this location and the unconstrained nature of the study area, it was not considered appropriate to set up a box model run for the assessment area. However, it is worth noting that the estimate of exchange using a tidal prism method is 1.9 days (Marine Scotland, 2012).

11.3 Hydrographic Assessment

11.3.1 Surface Flow

The site and meteorological data indicate that the discharge of freshwater into the surface will occur primarily at the head and northern side of the assessment area. The meteorological data indicate a moderate seasonal variation in freshwater discharge which will mean that any exchange driven by estuarine circulation will also have a seasonal variation.

The assessment area has relatively simple bathymetry, particularly to the south, and is wide open to the west at its mouth. There is no shallow sill across the mouth of the loch that will restrict exchange.

It is anticipated that tidal flows will follow the local bathymetry. A weak cyclonic (anti-clockwise) circulation may develop in the loch, with a somewhat enhanced flow along the northern shore, due to the freshwater input but there is no observational evidence to support this. The cumulative transport distance on each phase (flood/ebb) of the tide has been estimated at around 1.3 km within the assessment area.

It is likely that surface residual flows will be rather weak and in a seaward direction. Surface residual flows would be enhanced by winds blowing out of the loch, but this would necessitate winds from an easterly direction which are rather infrequent. More likely is a suppression of the surface flow with winds from a westerly direction.

11.3.2 Exchange Properties

Due to the open aspect of the assessment area and the prevailing conditions, it is anticipated that the assessment area will have a relatively short flushing time of order a few days. It is expected that the study site will be a moderately-well flushed system throughout most of the year with surface contaminants being dispersed in any surface residual flow.

There are no current meter data series available for the area and there is a complete lack of long term hydrographic data coverage for this area, particularly data sets with seasonal resolution. There is also rather little descriptive literature for the flow properties of the area. Therefore, the confidence level of this assessment is LOW.

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 Beag Shellfish Water Protected Area (SWPA) has slightly extended boundaries compared to the previous Loch Beag Shellfish Growing Water (SGW), see Figure 12.1. The SWPA designation covers Loch Beag and includes the production area and mussel farm. The designated SWPA for Loch Beag 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.

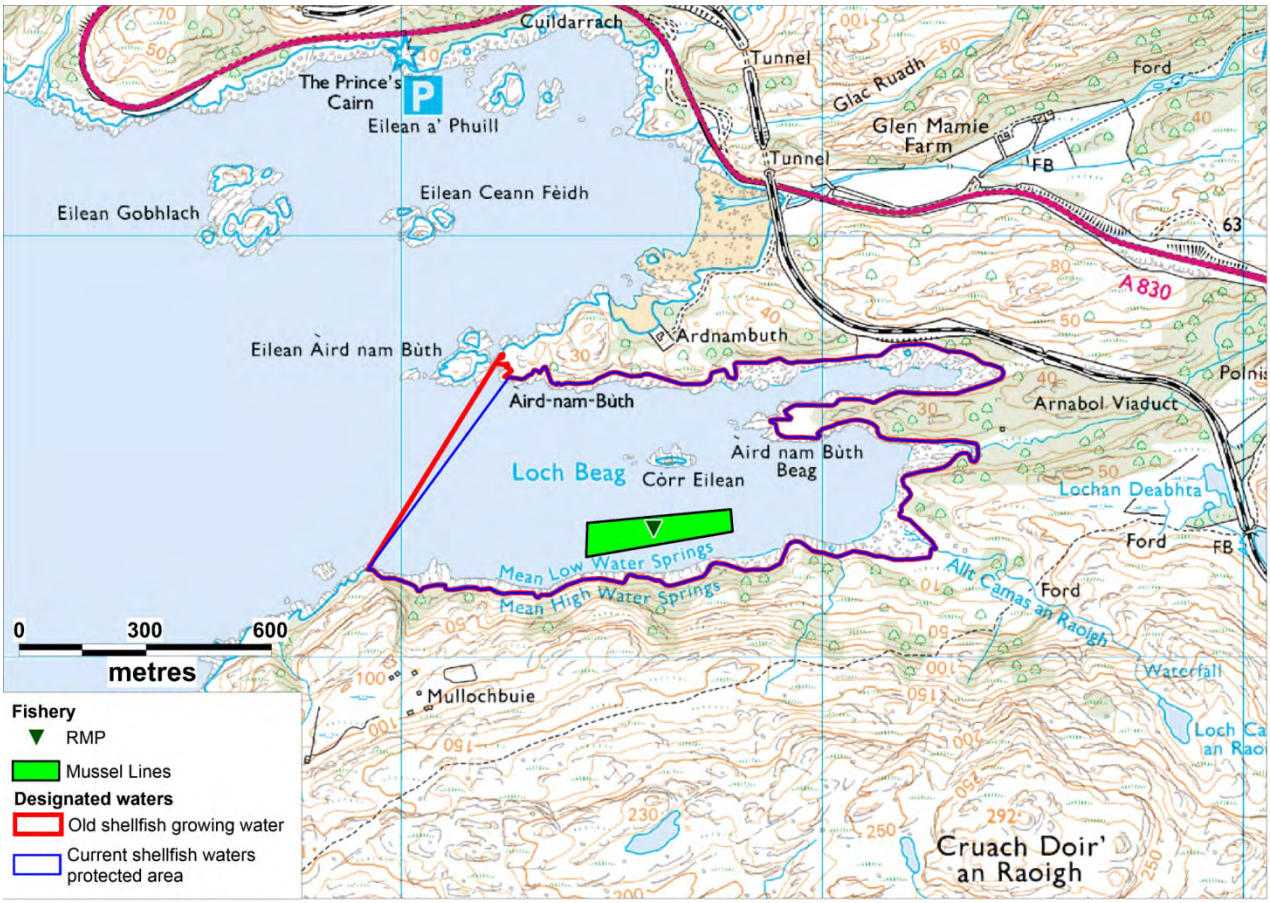


Figure 12.1 Designated shellfish water protected area – Loch Beag

Bathing Waters

There are no designated bathing waters within Loch Beag.

13. Historical *E. coli* Data

13.1 Validation of historical data

Results for all samples assigned against Loch Beag production area for the period 01/01/2009 to the 1/08/2014 were extracted from the FSAS database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. The data was extracted on 1/08/2014. All *E. coli* results were reported as most probable number (MPN) per 100 g of shellfish flesh and intravalvular fluid.

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

All 49 samples were reported as valid, were received within 48 hours of collection and had box temperatures of <8ºC. All samples plotted within the production area boundaries.

13.2 Summary of microbiological results

Sampling and result summaries of results assigned to Loch Beag between 2009 and 2014 are displayed in Table 13.1.

Table 13.1 Summary of historical sampling and results

Sampling Summary	
Production area	Loch Beag
Site	Ardnambuth
Species	Common mussels
SIN	HL-118-215-08
Location	Various
Total no of samples	49
No. 2009	9
No. 2010	6
No. 2011	9
No. 2012	10
No. 2013	10
No. 2014	5
Results Summary	
Minimum	<20
Maximum	2200
Median	<20
Geometric mean	20
90 percentile	20
95 percentile	512
No. exceeding 230/100g	3 (6%)
No. exceeding 1000/100g	1 (2%)
No. exceeding 4600/100g	0
No. exceeding 18000/100g	0

The sampling was least frequent in 2010, when only six samples were taken. More than half of the samples returned results of <20 *E. coli* MPN/100 g and only three samples gave results exceeding 230 *E. coli* MPN/100 g.

13.3 Overall geographical pattern of results

One unverified sample from 2013 did not have a reported sampling location and was thus omitted from the geographical analysis. The geographical locations of the remaining 48 sample results assigned to Loch Beag are mapped thematically in Figure 13.1.

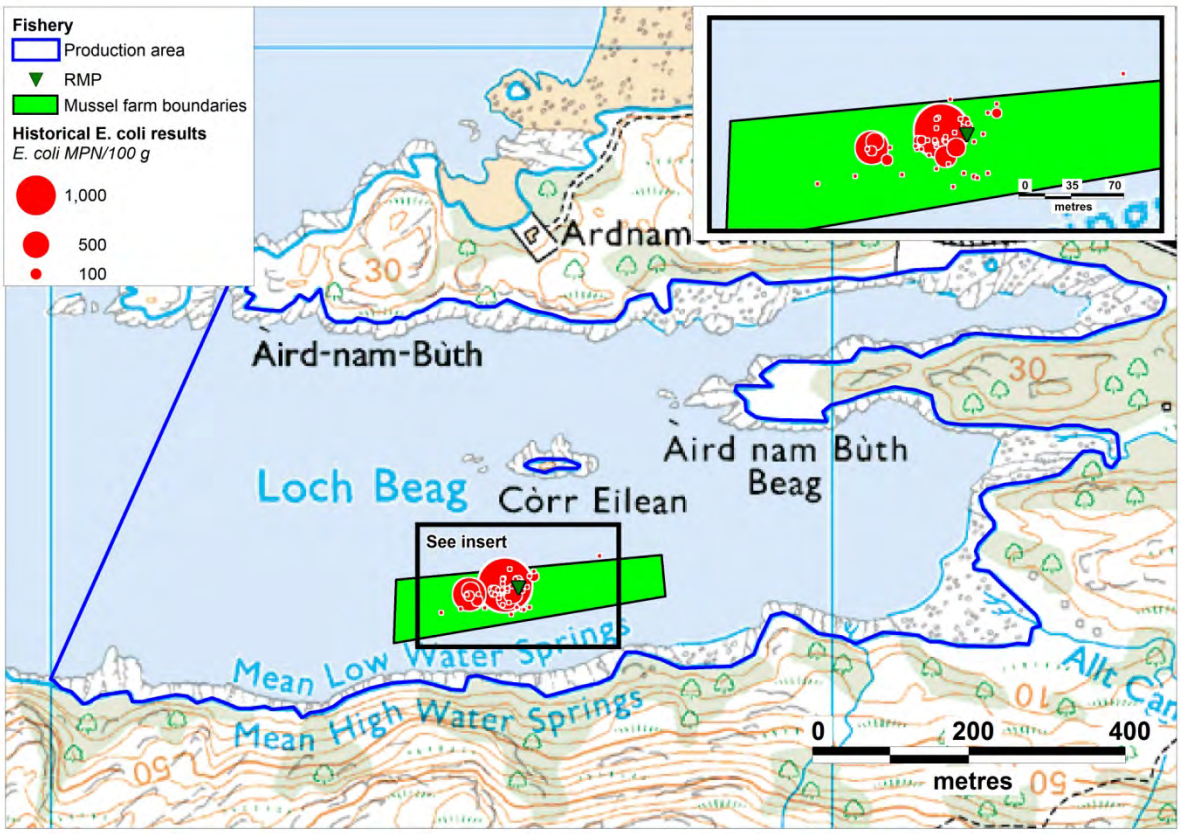


Figure 13.1 Map of reported sampling locations for common mussels at Loch Beag

The majority of samples (n=38) have been taken within 40 m of the RMP at NM 7260 8331 (site 1), with the remaining 10 samples plotting between 50 and 110 m west of the RMP (site 2). Most of the samples reported from the location west of the RMP were taken in 2009. The four samples that yielded results ≥230 *E. coli* MPN/100 g were taken across the two sampling groups but all to the west of the RMP.

13.4 Overall temporal pattern of results

A scatterplot of *E. coli* results against date for Loch Beag is presented in Figure 13.2. 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.

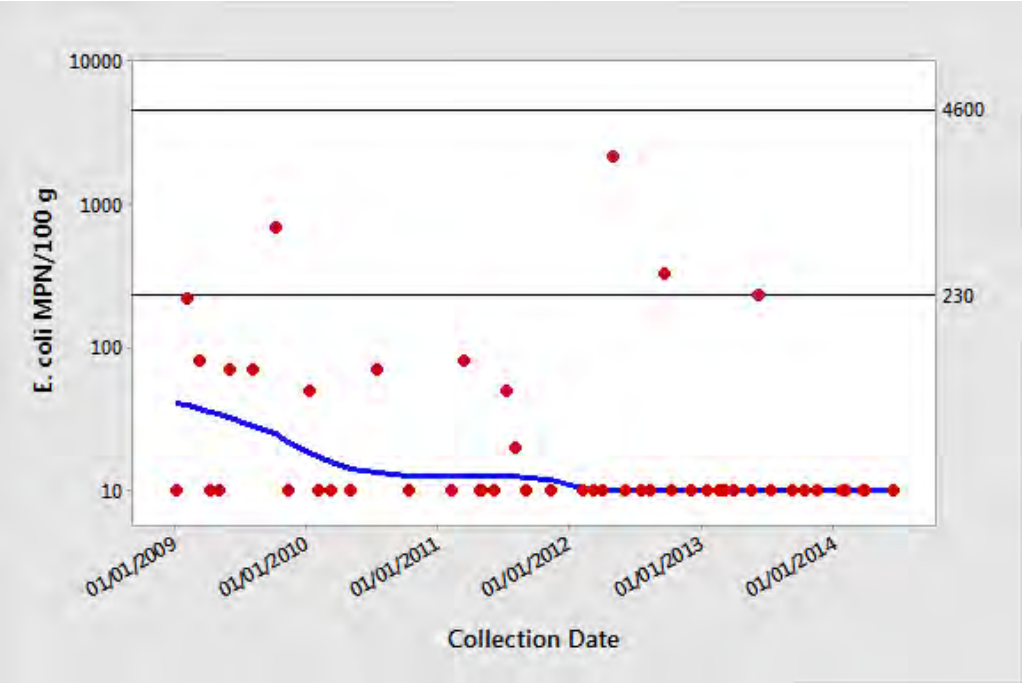


Figure 13.2 Scatterplot of *E. coli* results by collection date at Loch Beag, fitted with a lowess line

An overall decrease in contamination levels is shown by the trend line, associated with a greater proportion of results <20 *E. coli* MPN/100 g since the beginning of 2012. However, two of the three results >230 *E. coli* MPN/100 g were also recorded in 2012.

13.5 Seasonal pattern of results

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns in human distribution. All of these can affect levels of microbial contamination, causing seasonal patterns in results. A scatterplot of *E. coli* results by month, overlaid by a lowess line to highlight trends for Loch Beag is displayed in Figure 13.3. Jittering was applied to symbols at 0.02 (x-axis) and 0.001 (y-axis) respectively.

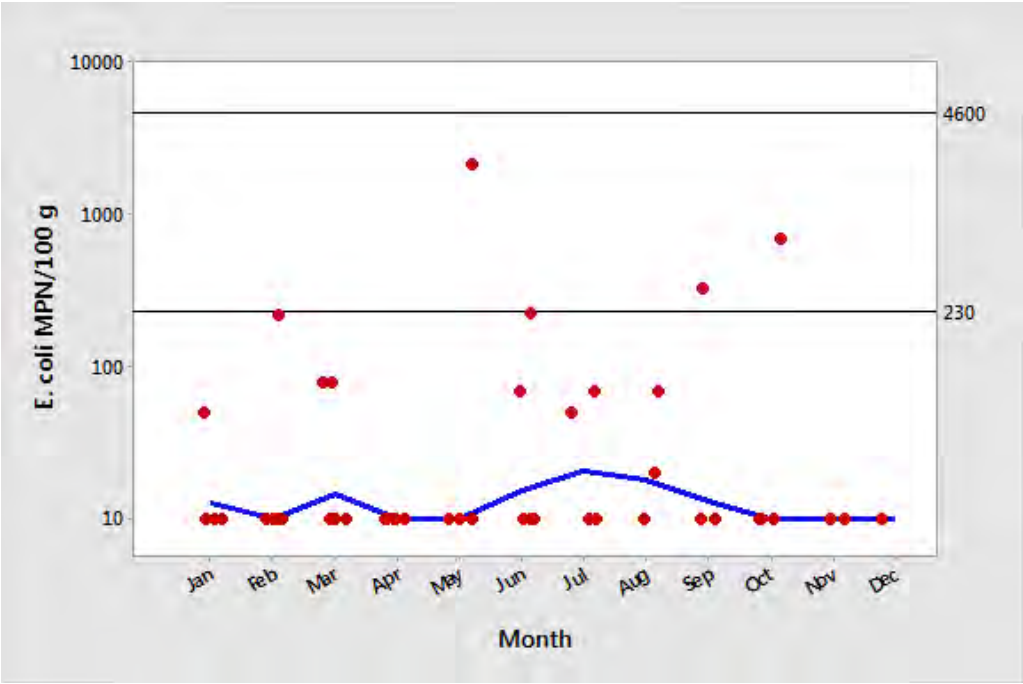


Figure 13.3 Scatterplot of *E. coli* results by month at Loch Beag, fitted with a lowess line

Sampling effort varied between months with only one sample taken in December, compared to five in March. Contamination levels appear to peak in July, though the highest results were associated with samples taken in May, September and October.

For statistical evaluation, seasons were split into spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). A boxplot of *E. coli* results by season for Loch Beag is presented in Figure 13.4.

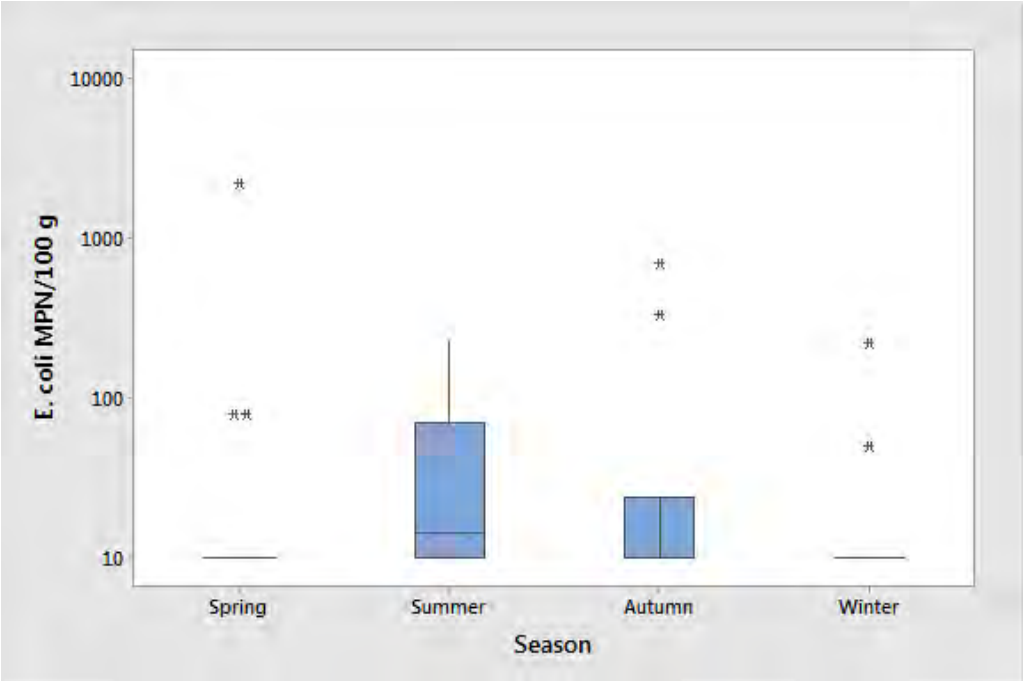


Figure 13.4 Boxplot of *E. coli* results by season at Loch Beag

No significant differences were found between *E. coli* results for Loch Beag by season (one-way ANOVA, p = 0. 811) (Appendix 3).

13.5.1 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.

13.5.2 Analysis of results by recent rainfall

The nearest weather station with available rainfall data was at Inverailort, approximately 5 km southeast of Loch Beag. Rainfall data was purchased from the Meteorological Office for the period of 01/01/09 - 31/12/2013 (total daily rainfall in mm). Data was extracted from this for all sample results at Loch Beag between 01/01/2009 – 31/12/2013.

Two-day rainfall

A scatterplot of *E. coli* results against total rainfall recorded on the two days prior to sampling for Loch Beag is displayed in Figure 11.5. Rainfall data was available for 41 out of the 49 results for Loch Beag. Jittering was applied to symbols at 0.02 (x-axis) and 0.001 (y-axis) respectively.

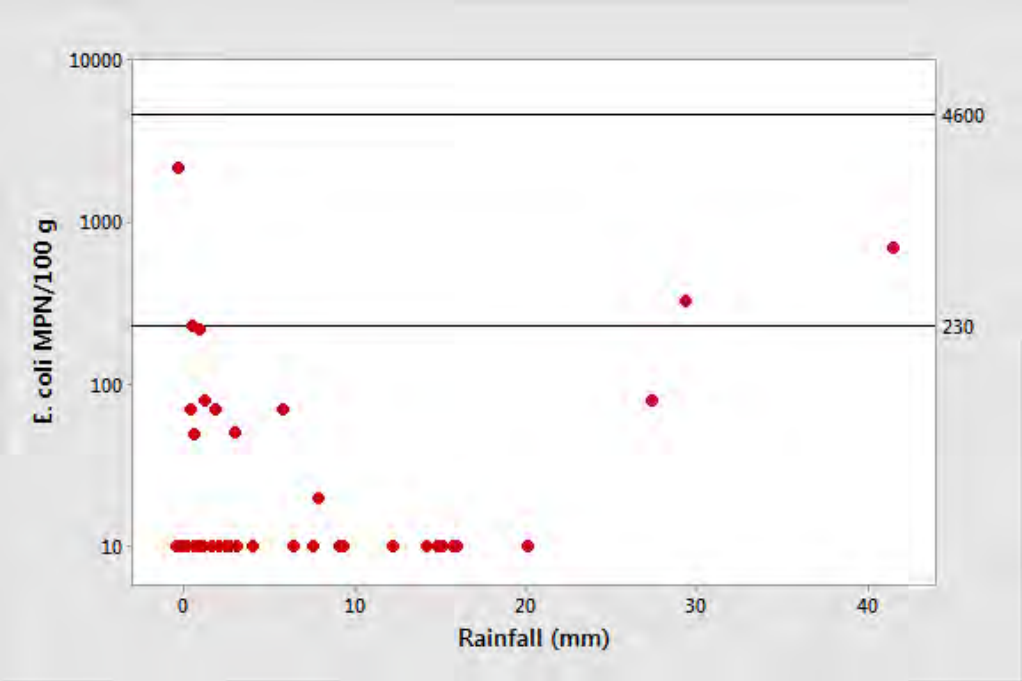


Figure 13.5 Scatterplot of *E. coli* results against rainfall in the previous two days at Loch Beag

No significant correlation was found between *E. coli* results and the previous two day rainfall (Spearman's rank correlation r = 0.029, p = 0.857).

Seven-day rainfall

Because the effects of heavy rainfall may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationship between rainfall in the previous seven days and sample results was investigated in an identical manner to the above. A scatterplot of *E. coli* results against total rainfall recorded for the seven days prior to sampling at Loch Beag is shown in Figure 13.6. Rainfall data was available for 40 out of the 49 Loch Beag results. Jittering was applied to symbols at 0.02 (x-axis) and 0.001 (y-axis) respectively.

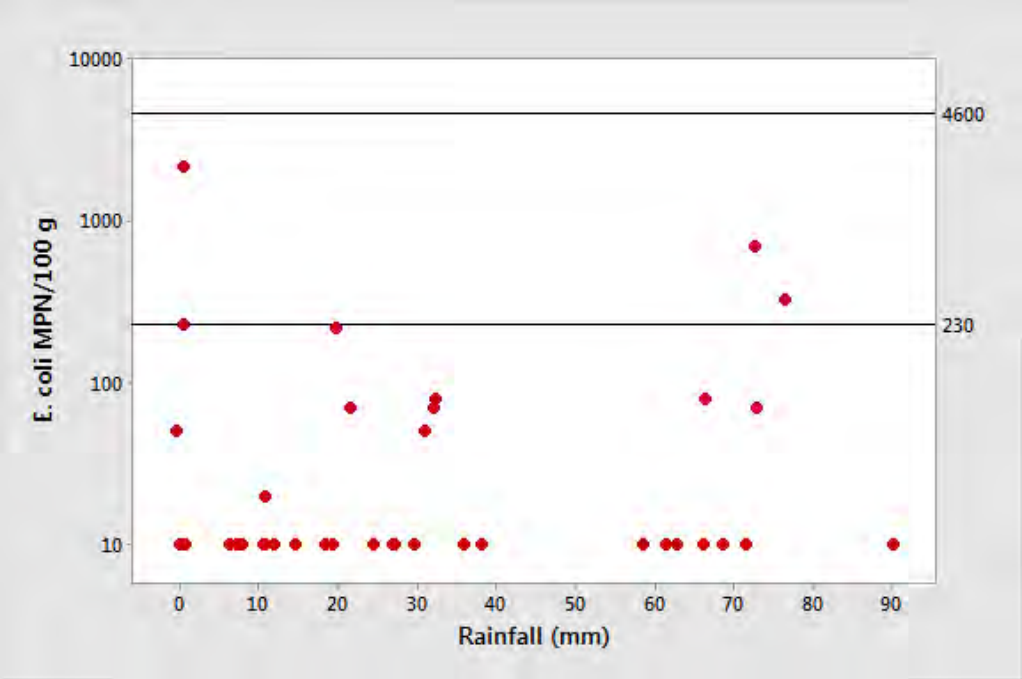


Figure 13.6 Scatterplot of *E. coli* results against rainfall in the previous seven days at Loch Beag

No significant correlation was found between *E. coli* results and the previous seven day rainfall (Spearman's rank correlation r = 0.109, p = 0.504).

13.5.3 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/new moon, at about 45º on a polar plot. The tides then decrease to the smallest (neap) tides, at about 225º, before increasing back to spring tides. A polar plot of *E. coli* results against the lunar cycle is shown for Loch Beag in Figure 13.7. It should

be noted local meteorological conditions (e.g. wind strength and direction) can also influence tide height, but are not taken into account in this section.

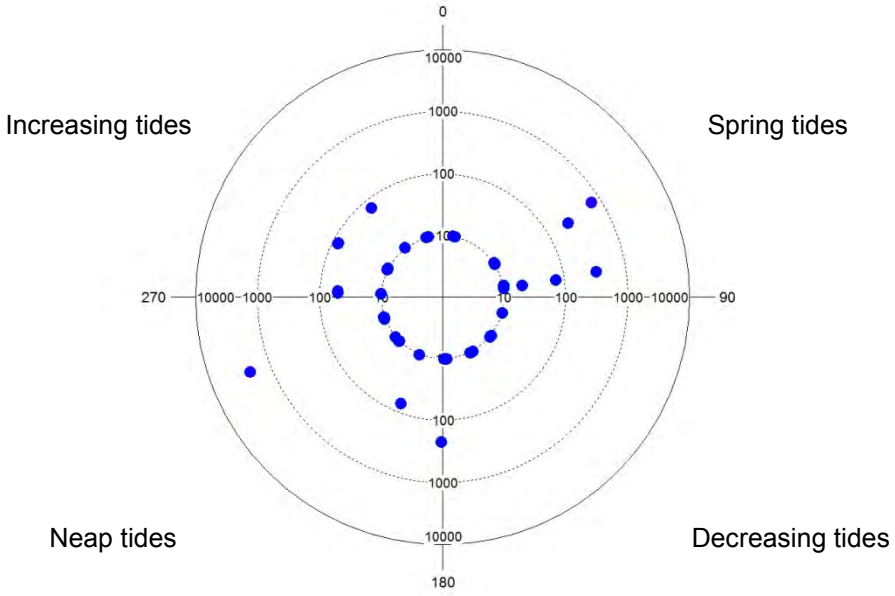


Figure 13.7 **Polar plots of *E. coli* results on the spring/neap tidal cycle at Loch Beag**

No significant correlation was found between $\log_{10}$ *E. coli* results and the spring/neap tidal cycle (circular-linear correlation r = 0.136, p = 0.425).

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 Beag is shown in Figure 13.8. High water is located at 0º on the polar plot and low water at 180º.

High and low water data for Loch Moidart was extracted from POLTIPS-3 in September 2014. This site was the closest to the production area (approximately 17 km to the southwest) and it is assumed that tidal state will be similar between sites.

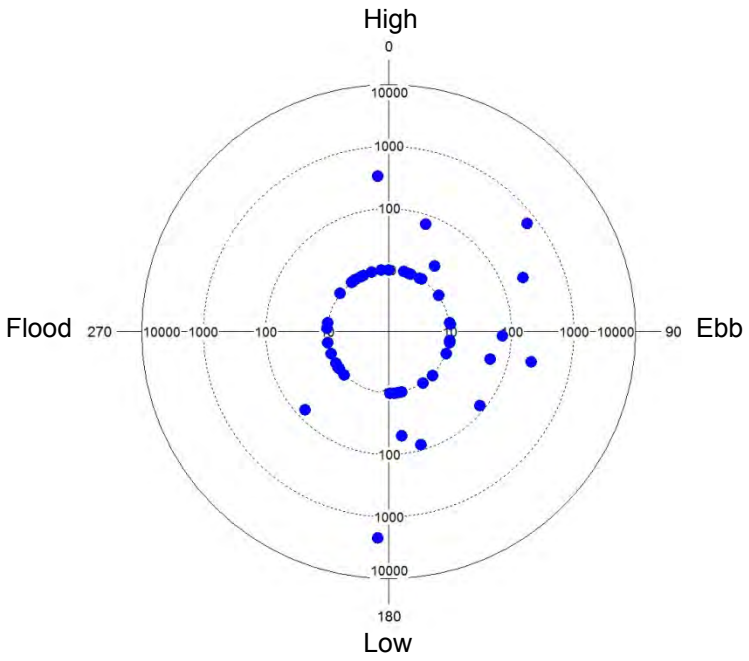


Figure 13.8 Polar plots of *E. coli* results on the high/low tidal cycle at Loch Beag

A significant correlation was found between $\log_{10}$ *E. coli* results and the high/low tidal cycle (circular-linear correlation r = 0.294, p = 0.019). Higher results were generally associated with an ebb tide, although the highest sample results occurred at high, flood and low tides.

13.5.4 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. A scatterplot of *E. coli* results against water temperature for Loch Beag is shown in Figures 13.9. Water temperature was recorded for 42 out of the 49 Loch Beag samples. Jittering of symbols was applied at 0.02 (x-axis) and 0.001 (y-axis) respectively.

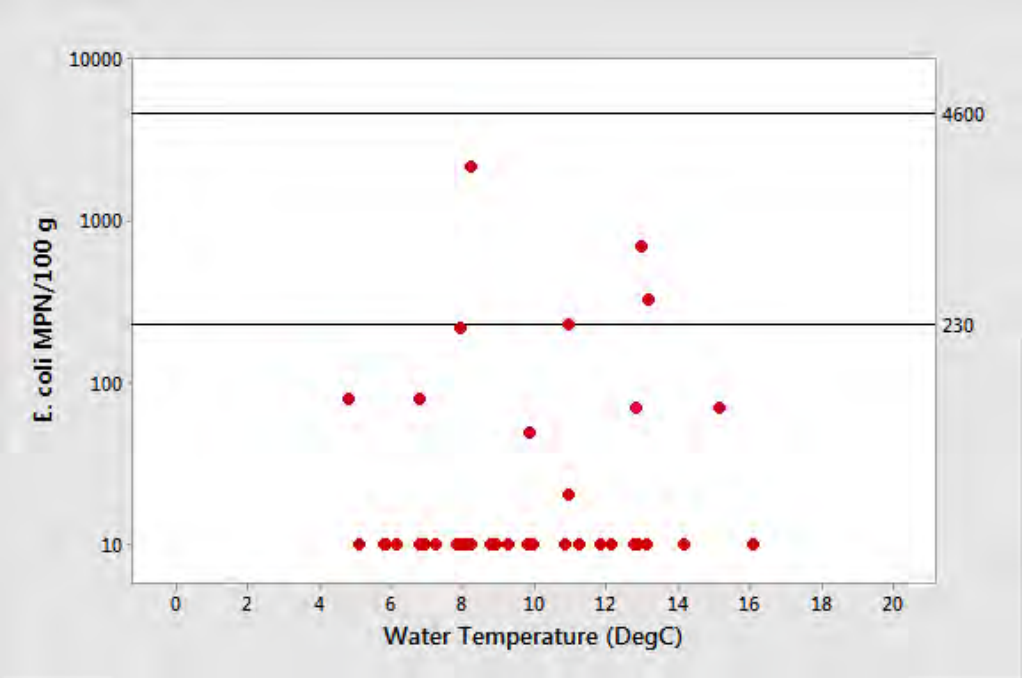


Figure 13.9 Scatterplot of *E. coli* results against water temperature at Loch Beag

No significant correlation was found between *E. coli* results and water temperature (Spearman's rank correlation r = 0.185, p = 0.241).

13.5.5 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence and hence freshwater borne contamination at a site. Owing to insufficient reported salinity results, no analysis of Loch Beag results by salinity was carried out for this report.

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

Three common mussel samples had results >230 *E. coli* MPN/100 g and are listed below in Table 13.2.

Table 13.2 Loch Beag 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)
06/10/2009	700	NM 7254 8330	41.1	74.4	13	23	Spring	High
01/05/2012	2200	NM 7258 8331	0.0	2.3	8	-	Neap	Low
19/09/2012	330	NM7259 8330	29.0	77.8	13	-	Spring	Flood

-No data available

The three high results were from samples were taken in May, September and October, with one sample taken in 2009 and two taken in 2012. All samples plotted a short distance west of the RMP. Rainfall appeared to be high for the previous two and seven days for two of the sample results, but not for the highest sample result which had zero rainfall for the previous two days and low rainfall for the previous

seven days. Water temperature varied between 8 and 13ºC, whilst salinity was only recorded for the 2009 sample, but was relatively low at 23 ppt. Two samples were taken on a spring tide and one on a neap tide. No apparent pattern was noted with regard to the high/low tidal cycle.

13.7 Summary and conclusions

Overall, contamination levels in sample results from Loch Beag have been low, with only three results greater than 230 *E. coli* MPN/100 g. A general decrease in contamination levels was evident from the beginning of 2012, with the majority of results after that date being less than 20 *E. coli* MPN/100 g.

The majority of samples have been taken close to the current RMP. The three samples with results greater than 230 *E. coli* MPN/100 g were taken to the west of that location.

No statistically significant difference was found between sample results and season, rainfall, water temperature or spring/neap tidal cycle. A statistically significant correlation was found between results and high/low tidal state, with higher results generally associated with an ebb tide. However, the three highest results were from samples taken on low, flood and high tides.

14. Shoreline Survey Overview

The Loch Beag shoreline survey was conducted on the 16th and 17th of June 2014. No rainfall was recorded in the 48 hrs prior to the survey.

The fishery consisted of a common mussel farm comprised of two, 300 m long-lines with 8 m droppers. Harvest was reported to normally take place year round. Two shellfish samples were taken at the southeast corner and to the northwest area of the mussel farm, one from 0 m depth and one from 8 m depth. Three of the four samples returned results of <18 *E. coli* MPN/100 g, with one sample returning a result of 20 *E. coli* MPN/100 g. All associated seawater samples returned results of 0 *E. coli* cfu/100 ml.

The surrounding shorelines are predominantly uninhabited, with only a few properties noted along the shorelines. A pipe noted below a house in Cuildarrach was sampled and returned a freshwater sample result of 270 *E. coli* cfu/100 ml. No obvious sewage discharges were noted during the survey.

Seven watercourses were sampled and measured. Sample results varied between <10 and 40 *E. coli* cfu/100 ml, with the highest result associated with the largest watercourse Allt a' Mhàma.

No hotels or B&B's were noted. A static caravan was noted on the eastern shore next to the Glac Ruadh burn. No official campsites or caravan parks were observed.

A rowing boat was also observed on the shore next to a wooden chalet at Arnabol Burn. Three buoys and a small storage platform were also observed in front of the house at Cuildarrach.

The surrounding land was recorded as mostly rough moorland with rocky outcrops and patches of natural deciduous forestry. The land was steep with cliffs immediately next to the shore in places. No farm animals or other agricultural activity were noted during the shoreline survey and no forestry, industrial or urban land was reported. Wildlife observations were limited to birds, with oystercatchers, common gulls and Grelag geese .

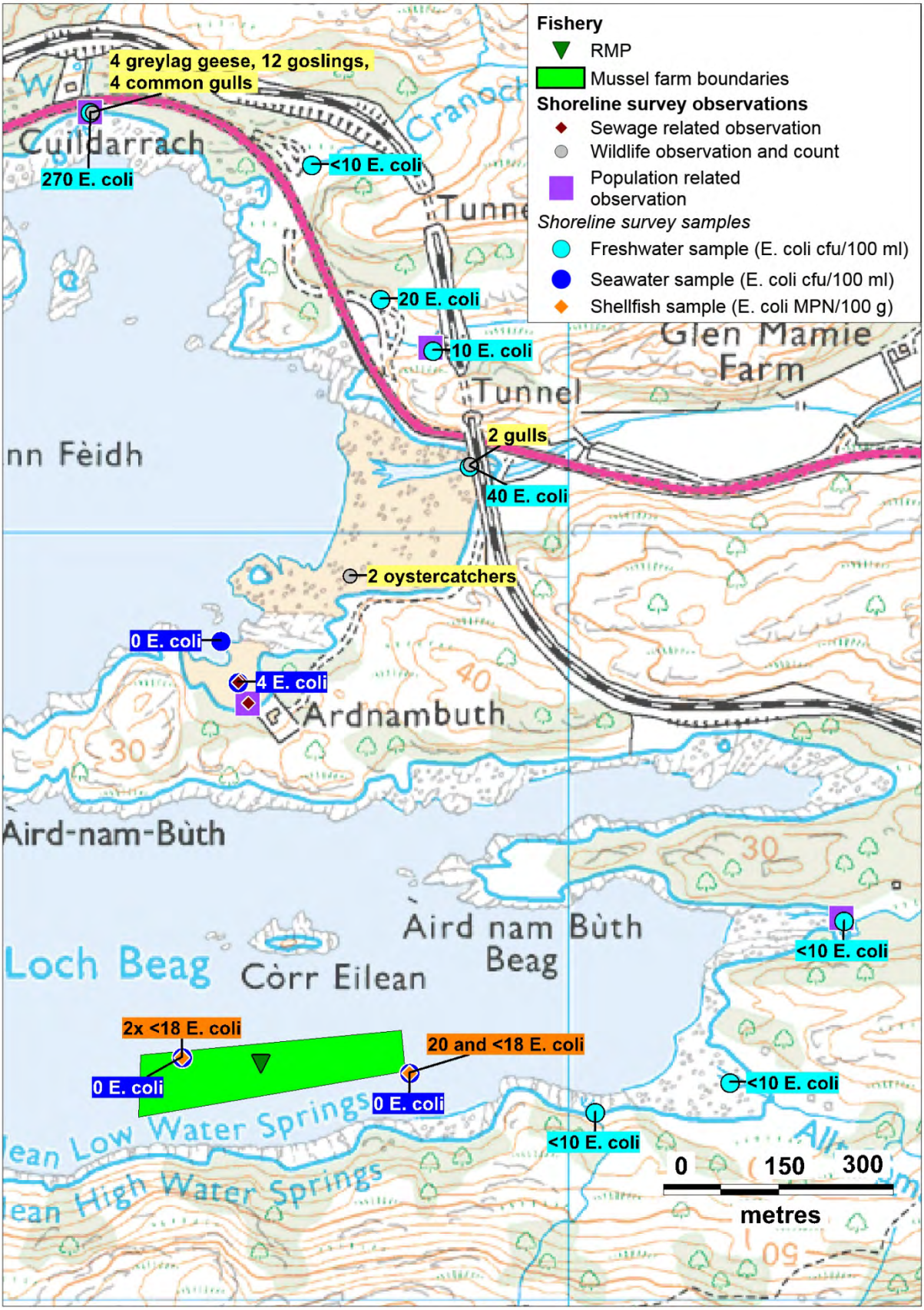


Figure 14.1 Map of shoreline survey observations at Loch Beag

15. Bacteriological Survey

A bacteriological survey was not undertaken at this site due to the relatively small size of the mussel farm and the spread of locations sampled during the routine classification monitoring programme.

16. Overall Assessment

Human sewage impacts

The area around Loch Beag is sparsely inhabited and potential sources of human faecal pollution are limited to a single community discharge presumed to serve three cottages and a small number private discharges (with PEs of 5-11). The consented discharges are located outside of Loch Beag as are a small number of dwellings that, although they do not have consented discharges, are assumed to have some form of septic tank arrangement. Due to their small number and size, they are unlikely to impact significantly at the mussel farm but may contribute to the background levels of *E. coli* in the area. One dwelling was observed approximately 600 m to the east of the mussel farm: although this is closer than the other potential sources, it is unlikely to have a significant impact at the farm due to the presumed small *E. coli* loading and the depth of water within Loch Beag.

Agricultural impacts

Any contributions of faecal contamination from livestock are expected to be low, but some contamination may arise from Glen Mamie Farm and Arisaig House, both located outside of Loch Beag.

Wildlife impacts

The two main sources of faecal contamination from wildlife will be seals and seabirds. Any impact will be sporadic in terms of both time and location.

Seasonal variation

There is likely to be some seasonal variation in the human population in the area due to the number of places offering tourist accommodation. The highest mussel *E. coli* results were seen between May and October but differences in the average *E. coli* results between seasons were not statistically significant.

Rivers and streams

Faecal contamination associated with watercourses will be low but those watercourses to the east of the mussel farm will potentially impact on the microbiological quality after rainfall.

Movement of contaminants

Tidal flows are expected to follow the local bathymetry. This may be modified by the effect of freshwater inputs but no evidence was available to demonstrate this effect. The cumulative transport distance on each phase (flood/ebb) of the tide has been estimated at around 1.3 km within the assessment area. Surface residual flows are

likely to be weak and in a seaward direction. These would be enhanced by winds blowing out of the loch, but easterly winds are relatively infrequent. A more likely effect is a suppression of the surface flow with winds from a westerly direction.

Salinity profiles taken at the time of the shoreline survey found little change in salinity with depth (<0.5 psu): the shoreline survey was conducted after a period of dry weather.

A significant correlation was found between the high/low tidal cycle and *E. coli* results but not between the spring/neap/tidal cycle and *E. coli* results. Higher results tended to be from samples taken around ebb tide.

Temporal and geographical patterns of sampling results

A general decrease in contamination levels was evident from the beginning of 2012, with the majority of results after that date being <20 *E. coli* MPN/100 g. The majority of samples have been taken close to the current RMP. The three samples with results >230 *E. coli* MPN/100 g were taken to the west of that location.

Conclusions

There are few identified sources of faecal contamination to the mussel farm in Loch Beag. Those that have been identified fall into two groups. The first is the consented discharges, watercourses and farms located around Loch nan Uamh and to the north and northwest of Loch Beag. These sources have small associated loadings and are further from the shellfish farm than the estimated particle transport distance. The other group of sources are the watercourses and a discharge presumed to be associated a dwelling to the east of the mussel farm. The estimated loadings from these sources are also small but may impact at the farm on an ebb tide.

17. Recommendations

The recommendations are summarized in Figure 17.1.

Production area

Due to the absence of significant sources of contamination within Loch Beag, it is recommended that the production area remains as currently defined: the area bounded by lines drawn between NM 7223 8370 and NM 7200 8319 extending to MHWS. The current RMP is located at NM 7260 8331.

RMP

It is recommended that the RMP be moved closer to the eastern end of the mussel farm in order to reflect the location of potential contamination sources within Loch Beag. The recommended location is NM 7276 8332.

Tolerance

It is recommended that a tolerance of 40 m be applied in order to allow for some movement of the mussel lines.

Depth of sampling

As no significant effects have been seen with depth, it is recommended that sampling be undertaken at a depth of between 1 and 3 m.

Frequency

It is recommended that sampling be undertaken on a monthly basis.

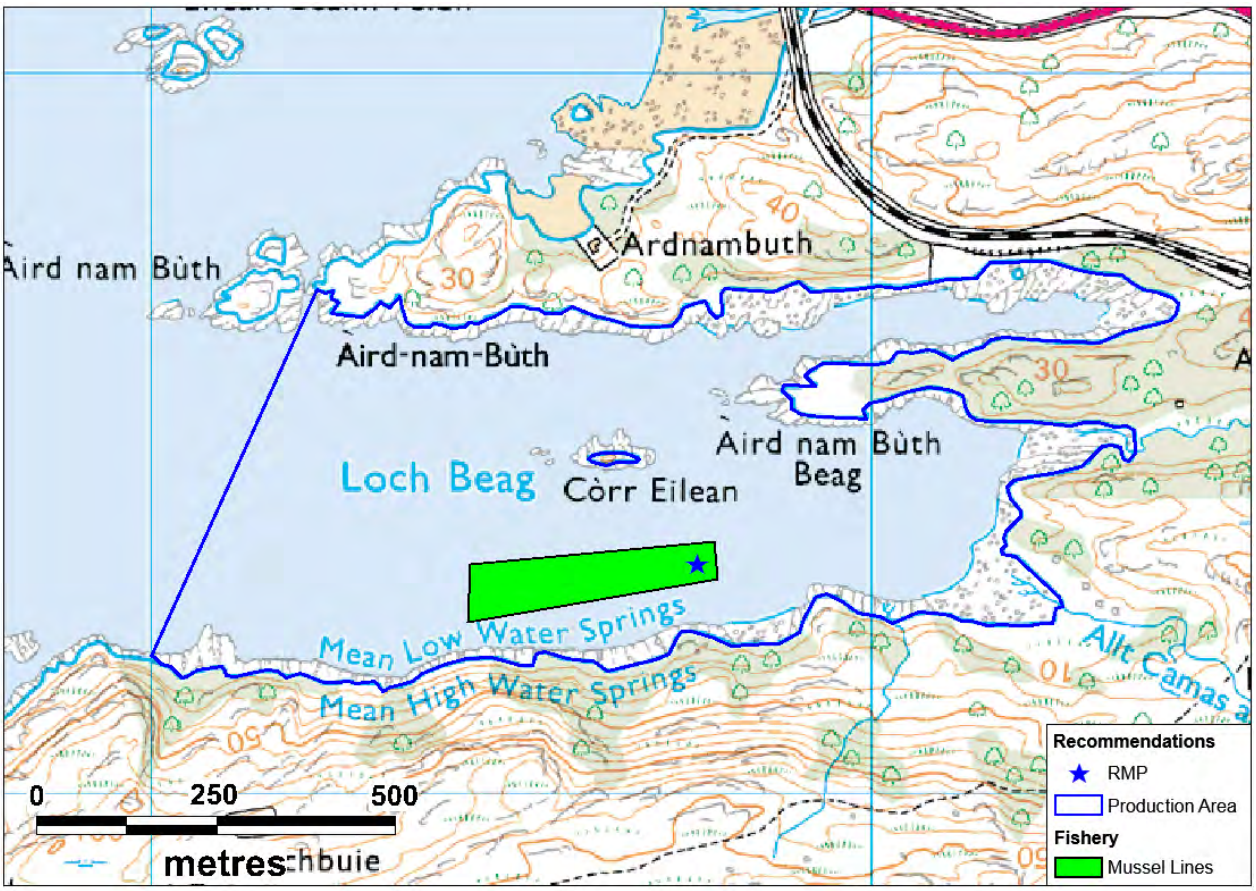


Figure 17.1 Map of recommendations at Loch Beag

18. References

Birds in Backyards, 2014. *Common Tern.* [Online] Available at: http://www.birdsinbackyards.net/species/Sterna-hirundo [Accessed 27 08 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.

Clyde Cruising Club, 2007. *Sailing Directions and Anchorages - Part 3 Ardnamurchan To Cape Wrath,* Glasgow: Clyde Cruising Club Publications Ltd..

Connor, D. W. & Little, M., 1998. Chapter 12: Clyde Sea (MNCR Sector 12)*. In: K. Hiscock, ed. *Marine Nature Conservation Review: Benthis marine ecosystems of Great Britain and the north-east Atlantic.* Peterborough: Joint Nature Conservation Committee, pp. 339-354.

Cramp, S., Bourne, W. & Saunders, D., 1974. *The Seabirds of Britain and Ireland.* New York: Taplinger.

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

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

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.

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.

Mitchell, I. P., Newton, S. F., Ratcliffe, N. & Dunn, T. E., 2004. *Seabird populations of Britain and Ireland: results of the Seabird 2000 census (1998-2002),* London: T & A D Poyser.

Scottish Anchorages, 2014. *Loch Beag.* [Online] Available at: http://www.scottishanchorages.co.uk/loch-beag/4536868921 [Accessed 27 08 2014].

Scottish Natural Heritage, 2006. *Sound of Arisaig (Loch Ailort to Loch Crann Traigh) Special Area of Conservation: Advice under Regulatin 33(2) of the Conservation (Natural Habitats, &c.) Regulations 1994 as ammended,* Inverness: Scottish Natural Heritage.

Special Committee on Seals, 2013. *Scientific Advice on Matters Related to the Management of Seal Populations 2013,* St Andrews: St Andrews University; Sea Mammal Research Unit.

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. **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.

Otters

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

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

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

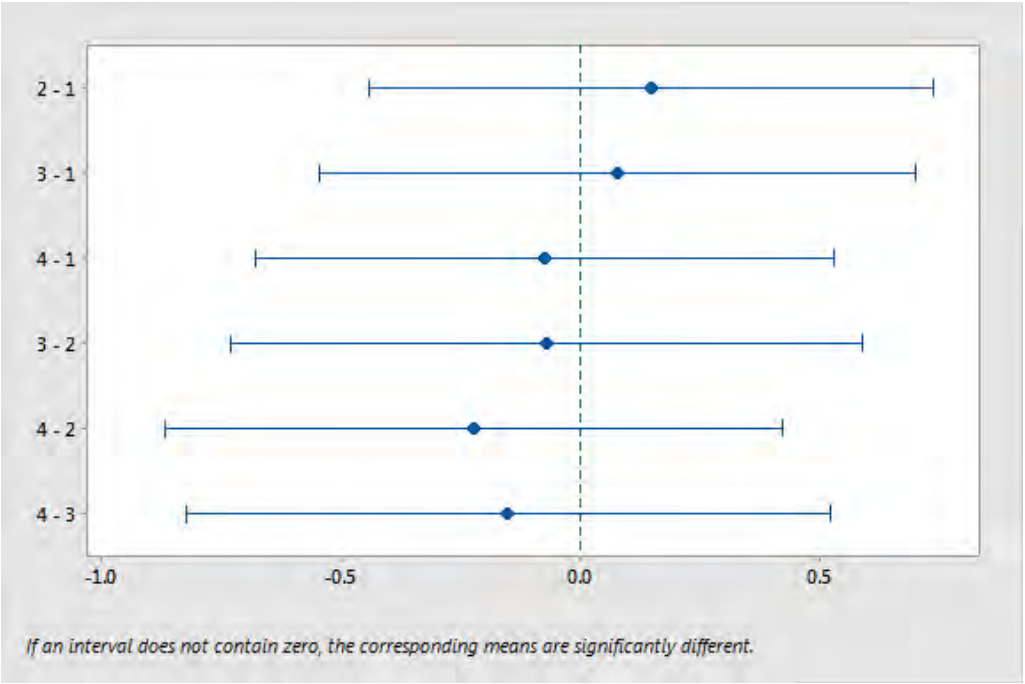
01/08/2014 12:34:12

One-way ANOVA: logec versus Season

```
Method

Null hypothesis         All means are equal
Alternative hypothesis  At least one mean is different
Significance level      α = 0.05

Equal variances were assumed for the analysis.


Factor Information

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


Analysis of Variance

Source  DF   Adj SS  Adj MS  F-Value  P-Value
Season   3   0.3227  0.1076     0.32    0.811
Error   45  15.1108  0.3358
Total   48  15.4334


Model Summary

       S   R-sq  R-sq(adj)  R-sq(pred)
0.579478  2.09%      0.00%       0.00%


Means

Season   N   Mean  StDev      95% CI
1       16  1.259  0.635  (0.968, 1.551)
2       12  1.408  0.484  (1.071, 1.745)
3       10  1.336  0.713  (0.967, 1.705)
4       11  1.186  0.437  (0.834, 1.537)

Pooled StDev = 0.579478
```

Tukey Pairwise Comparisons

```
Grouping Information Using the Tukey Method and 95% Confidence

Season   N   Mean  Grouping
2       12  1.408  A
3       10  1.336  A
1       16  1.259  A
4       11  1.186  A


Means that do not share a letter are significantly different.
```


2 - 1
3 - 1
4 - 1
3 - 2
4 - 2
4 - 3
-1.0
-0.5
0.0
0.5
If an interval does not contain zero, the corresponding means are significantly different.

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

Document Number	B0067_Shoreline 0033

Revision History

Revision	Changes	Date
A	Issue for internal review	24/06/2014
B	Second issue for internal review	27/06/2014
01	First formal issue to Cefas	25/07/2014
02	Second issue to client incorporating correction from issue 01	11/08/2014

	Name & Position	Date
Author	Eilidh Cole & Debra Brennan	24/06/2014
Checked	Andrea Veszelovszki	07/08/2014
Approved	Mark Hart	11/08/2014

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

Production area:	Loch Beag
Site name:	Àird-nam-bùth
SIN:	HL-118-215-08
Species:	Common Mussels
Harvester:	Ian MacKinnon
Local Authority:	Highland Council: Highland Lochaber
Status:	Existing area
Date Surveyed:	16/06/2014 – 17/06/2014
Surveyed by:	Debra Brennan & Eilidh Cole
Existing RMP:	NM 7260 8331

Area Surveyed

The stretch of shoreline on the northeast side of Loch Beag from Àird-nam-bùth House northwards until the Cranoch Burn near Cuildarrach.

A shorter section of the southeast shoreline of Loch Beag, from the watercourse named Allt Camas an Raoigh, below Cruach Doir' an Raoigh, northwards until the Arnabol Burn which runs through Polnish and under the Arnabol Viaduct.

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 – 9.

Weather

There was no rainfall recorded 48 hours prior to the survey. On the first day of the survey the weather was dry, bright and sunny. The temperature was around 18°C with a very slight northerly breeze which was too light to be recorded. Cloud cover was approximately 30% and the sea state was calm.

On the second day of the survey, conditions were similar. It was bright and sunny with a temperature of 17°C and a gentle W-NW breeze. Again, there was no rainfall.

Stakeholder engagement during the survey

Prior to the survey the sampling officer, Mr. Stephen Lewis, was very helpful and provided useful information regarding the survey site and fishery.

On the second day of the survey, the survey team met with Mr. Lewis who provided further details regarding the site. Mr. Lewis had also met with the harvester, Mr. Ian MacKinnon, the same morning. Mr. MacKinnon had kindly taken Mr. Lewis out on his boat to collect shellfish, seawater and CTD cast

data as he was not available to carry out this work with the survey team. Mr. MacKinnon was unfortunately also unavailable to meet with the survey team the day before, during the course of the shoreline part of the survey.

Fishery

Common mussels (*Mytilus edulis*) are cultivated within the Loch Beag fishery and harvest normally takes place all year round. However, at present, the site has limited stock due to poor mussel spat settlement. Because of this, there will likely be no harvest until October this year.

There are two mussel lines in total, each approximately 300 m long with 8 m droppers. Mussel samples were collected from both the top and the bottom of the droppers, as requested, at the locations marked in Figure 2.

Sewage Sources

The shellfish farm is located along the southern shore of Loch Beag. This is an area of the shoreline which is largely uninhabited.

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

Seasonal Population

No official campsites or caravan parks were seen in the area surrounding Loch Beag, however, on the eastern shore next to the Glac Ruadh watercourse there is a flat grassy area where one static caravan was observed. No hotels or B&Bs were observed in the area surrounding Loch Beag, nor were the any obvious signs of holiday lets.

Dwellings around the loch are very sparse and scattered and do not appear to be confined to any one particular area.

Boats/Shipping

No boats out on the water were observed at any point during the survey. Boats were only observed at Àird-nam-bùth House, where two rowing boats, two kayaks and one motor boat were observed in the garden. One mooring buoy was also observed in front of house. A rowing boat was also observed on the shore next to the chalet at the Arnabol Burn.

Three buoys and a small storage platform were observed on the water in front of the house at Cuildarrach.

Farming and Livestock

No sheep, cattle or other livestock were observed at any point during the shoreline survey. A farm was marked on the map on the eastern shore of Loch Beag, north of Àird-nam-bùth at Glen Mamie but this was much further back from the shoreline and was not observed during the survey.

Land Use

There does not seem to be any particular use of the land surrounding Loch Beag. The land has been mostly unchanged with no farming, grazing, forestry or industry. A train line runs along a large proportion of the shoreline near to the road in places.

Land Cover

The predominant land cover surrounding Loch Beag is rough moorland with rocky outcrops and patches of natural deciduous forestry. The land is steep in places with cliffy sections immediately next to the shore.

Watercourses

Seven watercourses were marked on the survey map to be sampled during the survey. All of these were sampled with an extra sample taken from the watercourse associated with waypoint 9, due to its proximity to the static caravan. The largest of the watercourses encountered, Allt a' Mhàma, was over 5 m wide and ran under the viaduct just north of Àird-nam-bùth. This was associated with waypoint 5. Five of the other watercourses sampled were reasonably small ranging between 72 cm and 1 m 45 cm wide. Arnabol Burn was larger at 2 m 51 cm width and was also sampled. This ran onto the shore from Polnish. One watercourse was directed into a pipe below a house at Cuildarrach and this was also sampled (Table 1, LBFW5, waypoint 13.). No other watercourses were observed during the shoreline survey.

Wildlife/Birds

Wildlife surrounding Loch Beag was scarce and only a few birds were observed. Species included oyster catchers, common gulls and Greylag geese. No other birds or wildlife were observed throughout the survey.

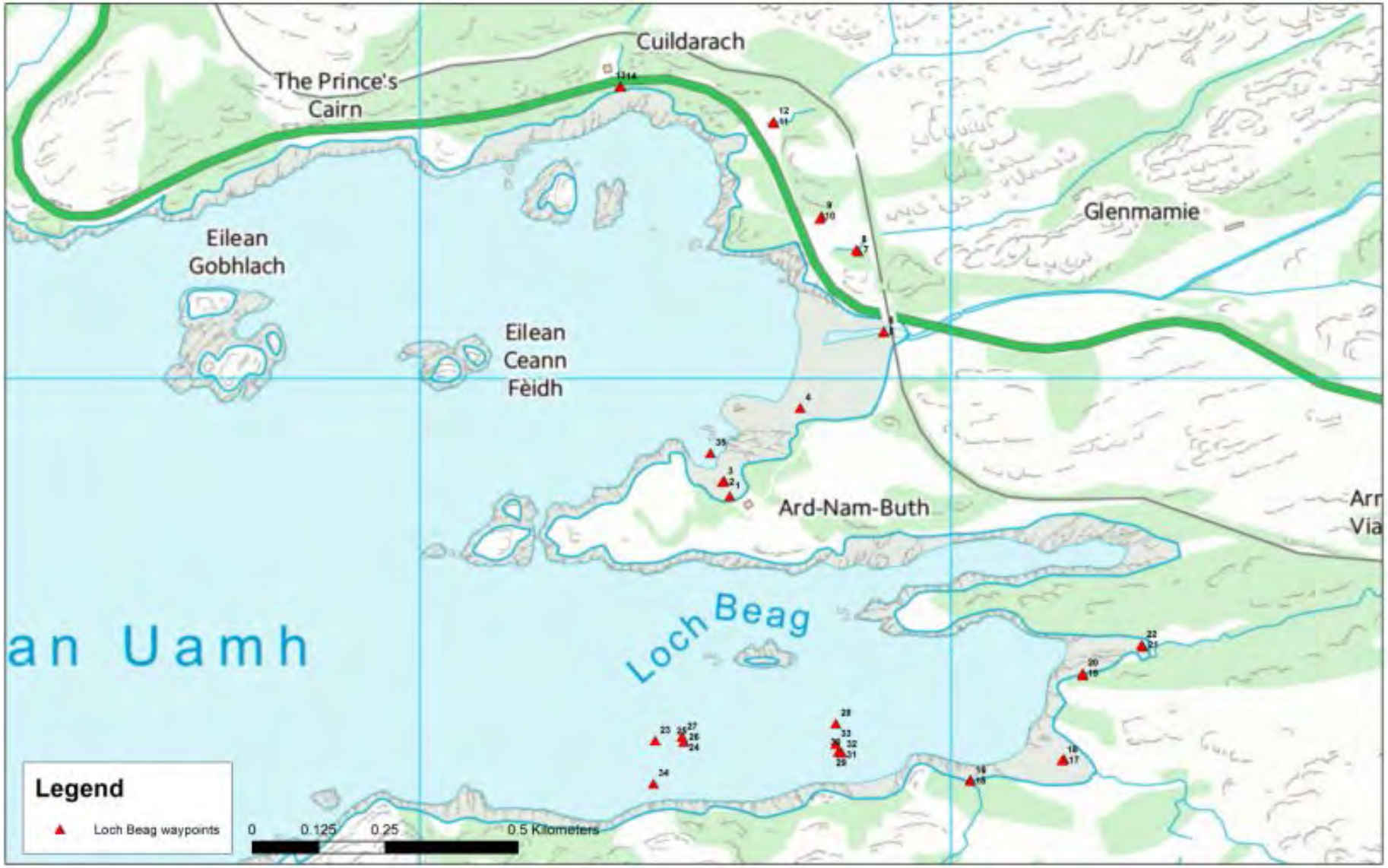


Figure 1. Loch Beag waypoints.

Figure 2. Loch Beag samples.

Table 1 Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
1	16/06/2014	13:46	NM 72583 83778	172583	783778			Àird-nam-bùth House. Concrete structure with pipe end but no discharge. Two rowing boats, two kayaks and one motor boat in garden. One mooring buoy at sea in front of house.
2	16/06/2014	13:49	NM 72572 83806	172572	783807	Figure 3		Pipe running into sea from house behind. Cannot see if discharging or not as covered by sea.
3	16/06/2014	13:49	NM 72570 83805	172570	783805	Figure 3	LBSW1	Planned seawater sample in front of house next to pipe.
4	16/06/2014	14:01	NM 72716 83944	172716	783944			Two oyster catchers on shore.
5	16/06/2014	14:06	NM 72872 84087	172873	784087	Figure 4	LBFW1	Planned freshwater sample from Allt a' Mhàma.
6	16/06/2014	14:07	NM 72873 84088	172873	784089	Figure 4		Large watercourse (Allt a' Mhàma) running under viaduct next to road. Width - 5 m 57 cm; Depth 1 - 24 cm; Flow 1 - 0.126 m/s; SD 1 - 0.007. Depth 2 - 20 cm; Flow 2 - 0.229 m/s; SD 2 - 0.015. Two seagulls flying overhead. Associated with waypoint 5.
7	16/06/2014	14:29	NM 72825 84238	172825	784238		LBFW2	Planned freshwater sample from Glac Ruadh.
8	16/06/2014	14:30	NM 72821 84242	172822	784242	Figure 5		Small burn (Glac Ruadh) running under road onto shore. One static caravan with one occupant on grassland next to burn. Width - 1 m 10 cm; Depth 9 cm; Flow - 0.116 m/s; SD - 0.003. Associated with waypoint 7.
9	16/06/2014	14:40	NM 72756 84305	172756	784305		LBFW3	Extra freshwater sample.
10	16/06/2014	14:40	NM 72753 84300	172753	784301			Extra water sample taken from another small burn just down from the static caravan. Width - 72 cm; Depth - 7cm; Flow - 0.024 m/s; SD - 0.002. Associated with waypoint 9.
11	16/06/2014	15:03	NM 72666 84480	172667	784481		LBFW4	Planned freshwater sample from Cranoch Burn.
12	16/06/2014	15:03	NM 72666 84483	172666	784483			Small burn (Cranoch Burn) running onto shore next to road. No birds or wildlife observed. Width - 1m 45cm; Depth - 6cm; Flow - 0.109 m/s; SD - 0.003. Associated with waypoint 11.
13	16/06/2014	15:30	NM 72377 84549	172377	784550	Figure 6	LBFW5	Planned freshwater sample from culvert below house at Cuildarrach.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
14	16/06/2014	15:31	NM 72378 84548	172379	784548	Figure 7		Width of culvert - 65 cm; Width of water - 32 cm; Water Depth - 7cm; Flow - 0.030 m/s; SD - 0.002. Four adult Greylag geese and 12 goslings on shore beyond house. Four common gulls also observed. Three buoys and a small storage platform on water in front of house. Associated with waypoint 13.
15	16/06/2014	18:21	NM 73036 83244	173037	783245		LBFW6	Planned freshwater sample, south shore.
16	16/06/2014	18:22	NM 73036 83242	173037	783243			Small river running onto shore. Width - 1 m 17 cm; Depth - 13 cm; Flow - 0.079 m/s; SD - 0.004. Three buoys on water near shore. Associated with waypoint 15.
17	16/06/2014	18:35	NM 73212 83283	173212	783284	Figure 8	LBFW7	Planned freshwater sample from Allt Camas an Raoigh.
18	16/06/2014	18:36	NM 73209 83281	173209	783281	Figure 8		Small river (Allt Camas an Raoigh) running onto shore. Width - 82 cm; Depth - 8 cm; Flow - 0.043 m/s; SD - 0.02. Associated with waypoint 17.
19	16/06/2014	18:51	NM 73247 83440	173248	783441			Waypoint taken in error.
20	16/06/2014	18:51	NM 73247 83445	173248	783445			Waypoint taken in error.
21	16/06/2014	19:14	NM 73361 83494	173361	783495		LBFW8	Planned freshwater sample from Arnabol Burn.
22	16/06/2014	19:14	NM 73358 83498	173358	783498	Figure 9		Small watercourse (Arnabol Burn) running down glen past wooden chalet onto shore. Width - 2 m 51 cm; Depth - 15 cm; Flow - 0.045 m/s; SD - 0.02. One rowing boat and one kayak on shore. Associated with waypoint 21.
23	17/06/2014	*	NM 72443 83318	172443	783318			NW corner of mussel lines
24	17/06/2014	*	NM 72497 83316	172497	783316		LBSF1 Top	Planned shellfish sample from top of the line
25	17/06/2014	*	NM 72497 83316	172497	783316		LBSF1 Bottom	Planned shellfish sample from bottom of dropper
26	17/06/2014	*	NM 72497 83316	172497	783316		LBSW2	Planned seawater sample
27	17/06/2014	*	NM 72783 83350	172783	783350			NE corner of mussel lines
28	17/06/2014	*	NM 72788 83297	172788	783297			SE corner of mussel lines
29	17/06/2014	*	NM 72794 83295	172794	783295		LBSF2 Top	Planned shellfish sample from top of the line
30	17/06/2014	*	NM 72794 83295	172794	783295		LBSF2 Bottom	Planned shellfish sample from bottom of dropper
31	17/06/2014	*	NM 72794 83295	172794	783295		LBSW3	Planned seawater sample
32	17/06/2014	*	NM 72440 83237	172440	783237			SW corner of mussel lines

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
33	17/06/2014	*	NM 72547 83859	172547	783859		LBSW4	Planned seawater sample in Àird-nam-bùth Bay

Photographs referenced in the table can be found attached as Figures 3 – 9.

Recording and sampling times for waypoints 23-33 were between 9:10 and 10:15 am on the 17th of June. This data was provided by the Sampling Officer and given to the team. The data was then converted into grid references as no GPS raw data were available.

Sampling

Seawater and freshwater samples were collected at the sites marked in Figure 2. An extra freshwater sample was taken at waypoint 9 due to its proximity to a static caravan.

Four common mussel samples were taken. Shellfish were sampled from both the surface and the ends (8m) of the droppers, as requested.

All the samples were transferred to a Biotherm 30 box with ice packs and posted to Glasgow Scientific Services (GSS) for *E. coli* analysis. All freshwater samples and seawater sample 1 (LBSW1) were received by GSS within 48 hours of collection. All other seawater samples and all shellfish samples were received by the lab the day after posting. The sample temperature on arrival at GSS ranged between 5.5°C and 5.6°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	16/06/2014	LBSW1	NM 72570 83805	Seawater	4	33.60
2	16/06/2014	LBFW1	NM 72872 84087	Freshwater	40	-
3	16/06/2014	LBFW2	NM 72825 84238	Freshwater	10	-
4	16/06/2014	LBFW3	NM 72756 84305	Freshwater	20	-
5	16/06/2014	LBFW4	NM 72666 84480	Freshwater	<10	-
6	16/06/2014	LBFW5	NM 72377 84549	Freshwater	270	-
7	16/06/2014	LBFW6	NM 73036 83244	Freshwater	<10	-
8	16/06/2014	LBFW7	NM 73212 83283	Freshwater	<10	-
9	16/06/2014	LBFW8	NM 73361 83494	Freshwater	<10	-
10	17/06/2014	LBSW2	NM 72497 83316	Seawater	0	34.87
11	17/06/2014	LBSW3	NM 72794 83295	Seawater	0	33.96
12	17/06/2014	LBSW4	NM 72547 83859	Seawater	0	34.51

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	Sample depth (m)	E. coli (MPN/100g)
1	17/06/2014	LBSF1 Top	NM 72497 83316	Common Mussels	0 m (surface)	<18
2	17/06/2014	LBSF1 Bottom	NM 72497 83316	Common Mussels	8 m	<18
3	17/06/2014	LBSF2 Top	NM 72794 83295	Common Mussels	0 m (surface)	20
4	17/06/2014	LBSF2 Bottom	NM 72794 83295	Common Mussels	8 m	<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 – Loch Beag

Figure 3. Pipe running into sea from house behind. Associated with waypoints 2 and 3. Site of seawater sample LBSW1.

Figure 4. Large watercourse (Allt a' Mhàma) running under viaduct. Associated with waypoints 5 and 6. Site of freshwater sample LBFW1.

Figure 5. Static caravan next to Glac Ruadh Burn. Associated with waypoint 8.

Figure 6. Culvert below house at Cuildarrach. Associated with waypoints 13 and 14. Site of freshwater sample LBFW5.

Figure 7. Three buoys and a small storage platform on water in front of house. Associated with waypoint 14.

Figure 8. Small river (Allt Camas an Raoigh) running onto shore. Associated with waypoints 17 and 18. Site of freshwater sample LBFW7.

Figure 9. Wooden chalet on shore next to the Arnabol Burn. Associated with waypoint 22.

6. Loch Beag CTD data

Data obtained during the shoreline survey. The locations of the casts are shown in Figure A6.1.

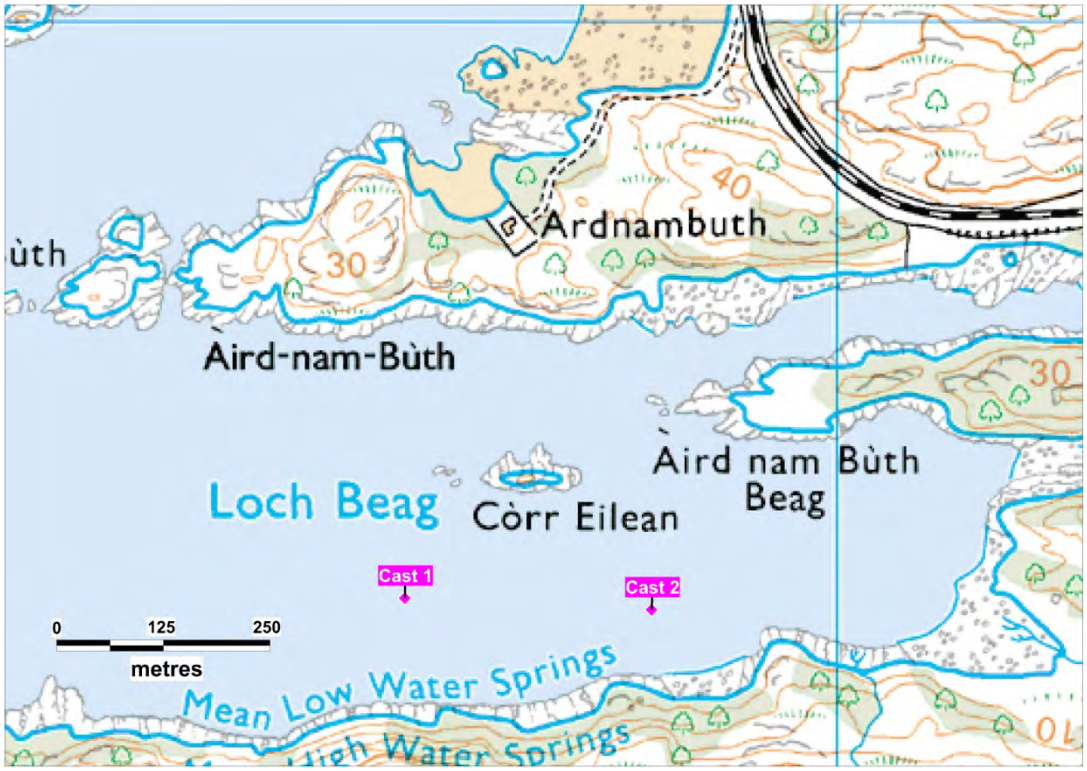


Figure A6.1 Location of CTD cast

CAST 1

Data Header

% Device	10G100653
% File name	10G100653_20140617_083714
% Cast time (local)	17/06/2014 09:37
% Sample type	Cast
% Cast data	Processed
% Location source	GPS
% Start latitude	56.8853049
% Start longitude	-5.7361749
% Start GPS horizontal error(Meter)	2.589999914
% Start GPS vertical error(Meter)	3.450000048
% Start GPS number of satellites	6
% Cast duration (Seconds)	68
% 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)
0.14907768	14.313919	33.58089618
0.447221386	14.32178858	33.52311285
0.745366736	14.23230571	33.59485615
1.043495847	14.15834482	33.62026607
1.341615247	14.07387585	33.63539643
1.639724475	13.93692838	33.64808221
1.937815032	13.71158127	33.70149631
2.23590104	13.40631778	33.54491194
2.533976882	13.14562172	33.64056538
2.832026674	13.04198275	33.67903464
3.130065159	12.97830056	33.69500804
3.428096275	12.93393721	33.71383754
3.726120426	12.89408734	33.73237939
4.024139603	12.85708439	33.73543871
4.322156324	12.82922133	33.73468741
4.620166086	12.75459018	33.76823304
4.918165012	12.68136504	33.79046347
5.216158049	12.5974805	33.77787665
5.514145996	12.50135446	33.7874046
5.812125742	12.42674357	33.80494836
6.110096729	12.38028656	33.83196839
6.408062311	12.35060746	33.83099323
6.706022182	12.32703337	33.86645466
7.003975366	12.29187469	33.87278863
7.301923267	12.2202003	33.88391491
7.599870074	12.13459185	33.84072228
7.89781417	12.05164782	33.86355602
8.195747379	11.99560204	33.90030087
8.49367377	11.97190369	33.90157862
8.791599805	11.96042956	33.89192191
9.089525699	11.93946078	33.89195251
9.387446685	11.88911702	33.91513619
9.727184205	11.88817773	33.90200409

CAST 2

Data Header

% Device	10G100653
% File name	10G100653_20140617_090014
% Cast time (local)	17/06/2014 10:00
% Sample type	Cast
% Cast data	Processed
% Location source	GPS
% Start latitude	56.8853255
% Start longitude	-5.7314253
% Start GPS horizontal error(Meter)	2.609999895
% Start GPS vertical error(Meter)	4.590000153
% Start GPS number of satellites	6
% Cast duration (Seconds)	52.2
% 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)
0.149103093	14.65328969	33.45238952
0.447282676	14.59451169	33.48239946
0.745457887	14.5179955	33.51382295
1.043623492	14.44177049	33.52291259
1.341780996	14.37301851	33.54319411
1.639930804	14.33377752	33.5589018
1.93807265	14.24926236	33.57735011
2.236207355	14.1494803	33.56933638
2.534330502	14.04650028	33.62232324
2.832430773	13.91783327	33.70755042
3.130506356	13.69642262	33.74532432
3.428583547	13.5063517	33.58091814
3.72666171	13.23689161	33.61298445
4.024712229	13.005793	33.69364755
4.3227355	12.8341662	33.74862143
4.620744211	12.70889758	33.74436624
4.918744822	12.60253711	33.75896543
5.216734429	12.52089862	33.79176556
5.514713855	12.47636348	33.81474356
5.812686546	12.44316664	33.82913639
6.110654627	12.39978004	33.83358013
6.408619052	12.36708493	33.83965686
6.706578155	12.31139363	33.8558722
7.004531591	12.25969999	33.86034279
7.302478814	12.19720019	33.87979228

Depth (Meter)	Temperature (Celsius)	Salinity (Practical Salinity Scale)
7.600418627	12.12836595	33.890738
7.898354675	12.08423617	33.88245515
8.196286062	12.01662521	33.90173204
8.49420907	11.95003836	33.92102303
8.792126378	11.90790553	33.92282697
9.090046011	11.89826235	33.8848492
9.387973622	11.83541194	33.83154867
9.685894382	11.68321465	33.8907338
9.853871552	11.67862796	33.90624748