Scottish Sanitary Survey Report

Sanitary Survey Report
Loch Spelve: Inverlussa and Rubha na Faing
AB-200 & AB-202
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Partner Organisations

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

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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 provisionally classified mussel fishery at Loch Spelve: Inverlussa and Rubha na Faing 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).

Loch Spelve is a sealoch on the south east coast of the Isle of Mull, approximately 16km west of Oban. Within Loch Spelve, the Inverlussa and Rubha na Faing production areas occupy the northern arm of the loch and contain six long-line mussel farms between them.

The human population in the area is very low. There are a small number of identified private septic tanks around the area that are consented to discharge to watercourses or soakaways. The watercourses in the area will constitute the most significant sources of contamination to the fisheries and there will also be direct runoff from pasture containing faecal material from farm animals. These sources are expected to have the greatest effect at the mussel lines located towards the northwestern end of the loch. Some contamination will also arise from wildlife, predominantly seabirds. The predicted transport distance within the loch is estimated to be between 0.4 and 1.2 km over each ebb or flood tide and so only sources of contamination relatively close to each set of mussel lines will be expected to affect the microbiological quality of those lines.

The assessment of pollution sources and historical microbiological data leads to the conclusion that there will not be a marked difference in the level of contamination between the different mussel sites and so it is recommended that the present two production areas be combined into one. In order to reflect the potential sources at the northwestern end of the loch, it is recommended that the RMP be moved to the northern end of the Ardura site.

Sampling Plan

Production Area	Loch Spelve: North
Site Name	Ardura
SIN	To be determined
Species	Common Mussels
Type of Fishery	Long-line
NGR of RMP	NM 6995 2995
East	169950
North	729950
Tolerance (m)	40
Depth (m)	1-3
Method of Sampling	Hand gathered
Frequency of Sampling	Monthly
Local Authority	Argyll and Bute Council
Authorised Sampler(s)	William MacQuarrie Ewan McDougall Allison Hardie Heather Harley
Local Authority Liaison Officer	Ewan McDougall
Production Area	The area bounded by lines drawn between NM 6922 2862 and NM 7100 2739, and between NM 7100 2739 and NM 7100 2793, extending to MHWS.

Report

1. General Description

Loch Spelve is a sea loch on the south east coast of the Isle of Mull off the west coast of Scotland within the Argyll and Bute council area. The loch opens on its southeastern side to the Firth of Lorn.

The area surrounding Loch Spelve is sparsely inhabited with population centres at Croggan in the south and Ardura in the North West coastline.

Loch Spelve is comprised of two arms extending from a narrow entrance channel. The channel has an east-west orientation while the arms are aligned northeast to southwest (see Figure 1.1). The arms have an overall length of 7.7 km. The width is generally between 0.5 and 1 km and is 1.5 km at its widest. The entrance is 3 km in length and 500 m wide. The maximum recorded depth is 58 m.

A sanitary survey had previously been undertaken in 2012 for the Loch Spelve: Croggan Pier Pacific oyster production area.

This sanitary survey was undertaken on the classified mussel fisheries at Loch Spelve: Inverlussa And Rubha Na Faing 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). These production areas were 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.

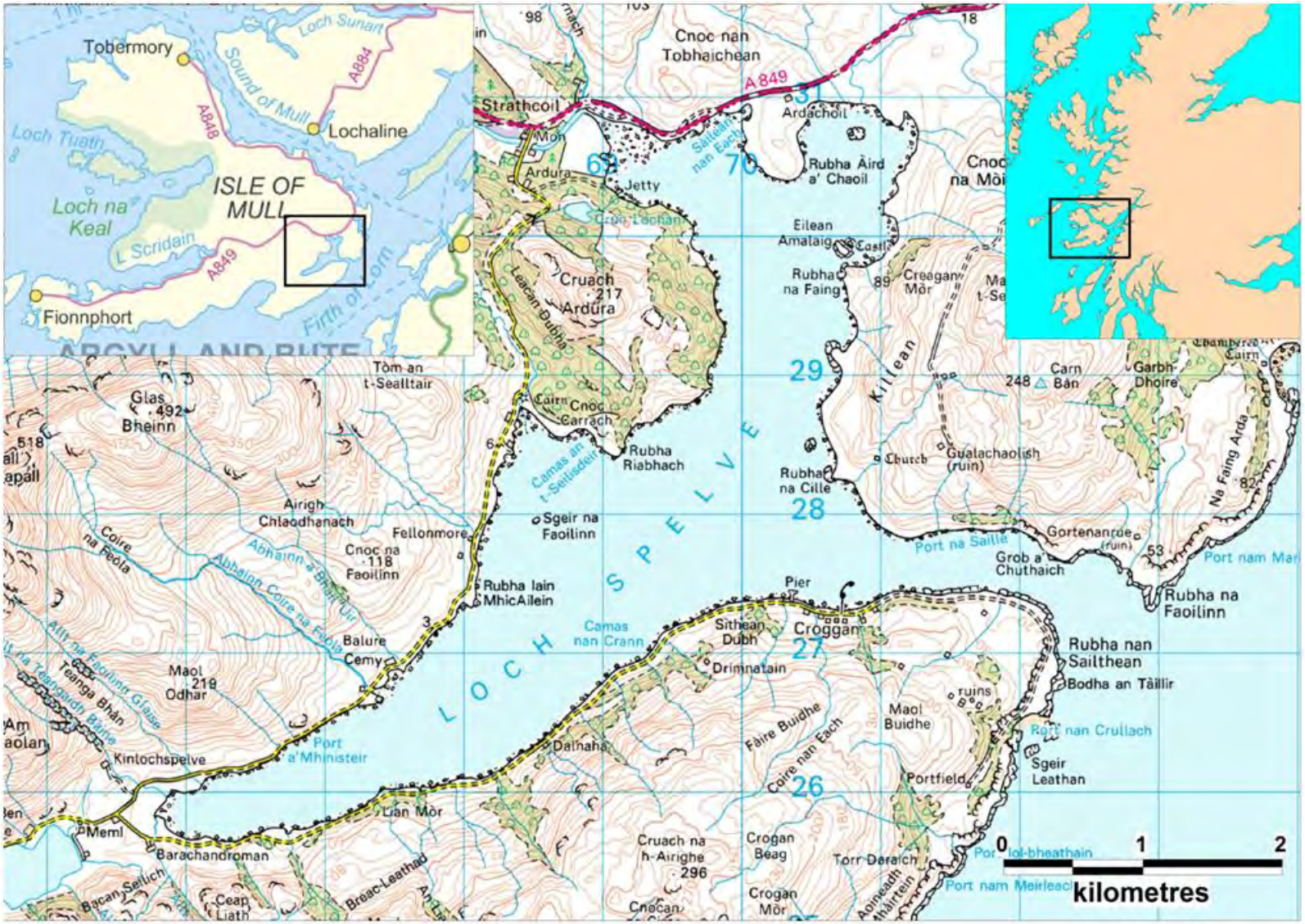


Figure 1.1 Location of Loch Spelve: Inverlussa And Rubha Na Faing

2. Fishery

There are two designated production areas within Loch Spelve. These are Loch Spelve Inverlussa and Rubha na Faing. Three sites are given in the 2014/15 FSAS classification listing. These are shown in Table 2.1.

Table 2.1 Loch Spelve: Inverlussa And Rubha Na Faing Area shellfish farms

Production area	Site	SIN	Species	RMP
Loch Spelve: Inverlussa	Inverlussa	AB-200-056-08	Common Mussels	
	Site 1	AB-200-057-08	Common Mussels	NM 7027 3018
Loch Spelve: Rubha na Faing*	Rubha na Faing	AB-202-059-08	Common Mussels	NM 7039 2833

Note:*The production area and site name are given as “Rhuba na Faing” in the classification listing. However, the OS map gives the geographical locality as “Rubha na Faing” and so the latter spelling has been used in this report.

The current production area for Loch Spelve: Inverlussa is defined as the area north of line drawn between NM 6966 3000 and NM 7113 3000.

The current production area for Loch Spelve: Rubha na Faing is defined as the area bounded by points lines drawn between NM 6966 3000, NM 7113 3000, NM 6922 2862, NM 7100 2740, NM 7100 2790.

The 2014 shoreline survey identified six long-line common mussel (*Mytilus edulis*) sites within the two production areas.

The sites identified during the shoreline survey are called: Site 3, Castle, Killean, Site 1, South Ardura and Ardura. Only Site 1 is given the same name as a site in the classification listing: however, the site identified as Site 1 during the shoreline survey does not appear to be the same as that given in the classification listing (see below).

The fish farm locations, as reported in the shoreline survey, are plotted in Figure 2.1. The current extent of Site 3 plots within the Loch Spelve: Inverlussa production area. Killean, Site 1, South Ardura and Ardura plot within the Loch Spelve: Rubha na Faing production area. The Castle Site straddles the boundary between the two production areas. Site 1 in the classification listing is identified against Loch Spelve: Inverlussa while the site identified as Site 1 during the shoreline survey plots within the Loch Spelve: Rubha na Faing production area.

At the time of the shoreline survey, three lines were observed at Site 3, five at Castle, six at Killean, four at Site 1, six at South Ardura, and seven at the Ardura site.

The present RMP for Loch Spelve: Inverlussa (NM 7027 3018) is located near the southeastern extent of Site 3 while the RMP for Loch Spelve: Rubha na Faing (NM 7039 2833)is located at the northwestern extent of the Killean site.

An adjacent production area (Loch Spelve: Croggan Pier) abuts the southern end of the Rubha na Faing production area and was covered under a separate sanitary survey in 2012.

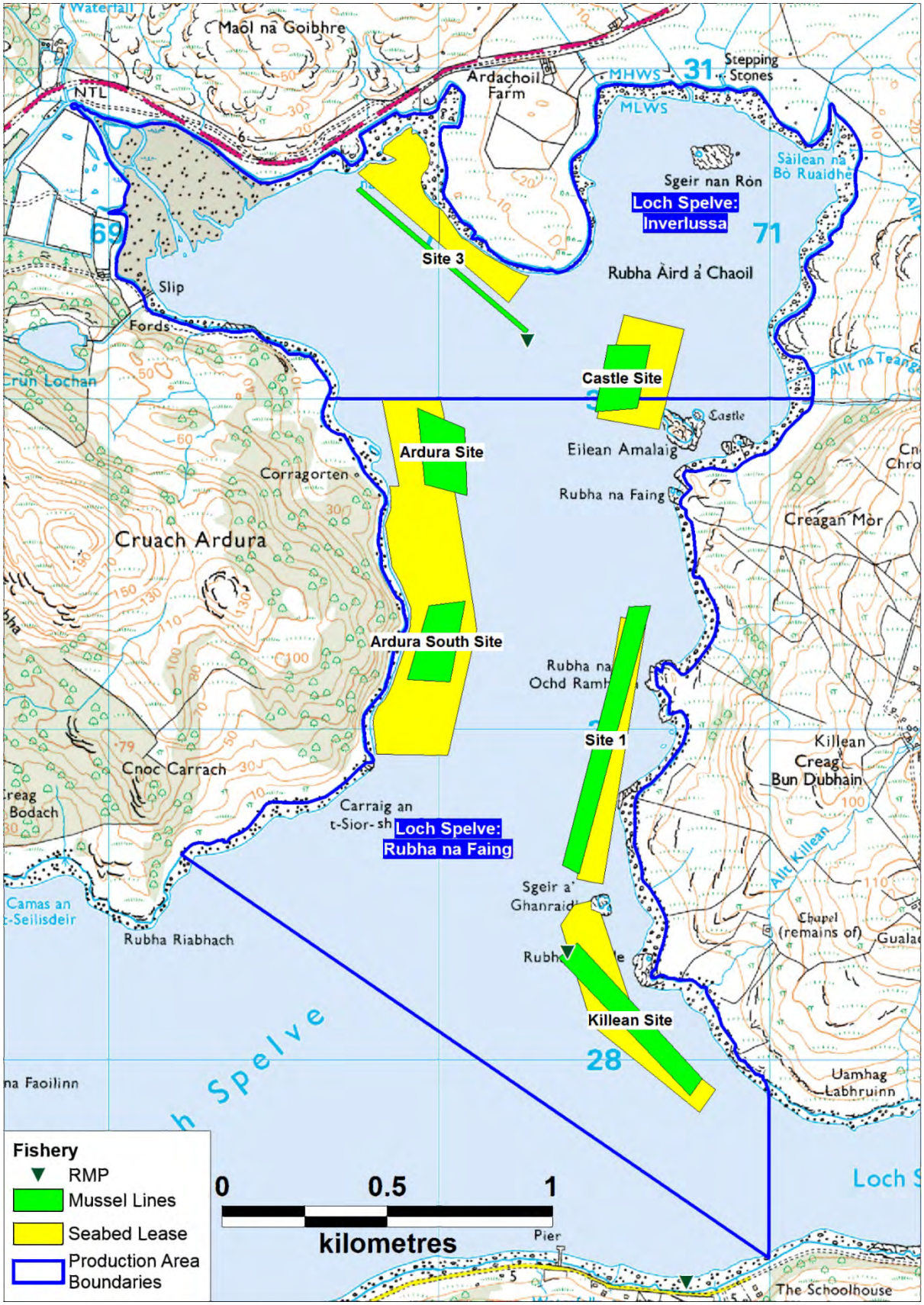


Figure 2.1 Loch Spelve Mussel Fishery

3. Human Population

Information on the population within the vicinity of the Loch Spelve production area was obtained from the General Register Office for Scotland. The last census was undertaken in 2011. The population densities in the census output areas immediately surrounding the shellfish farms in Loch Spelve are shown in Figure 3.1. The population density is low in all census output areas bordering the fishery. However, the census output areas vary in size and the population within them will not be evenly distributed.

Table 3.1 Census output area and population – Loch Spelve

Census Output Area ID	Population	Area (km^2)	Population density (people/km^2)
S00069244	96	71	1.4
S00069214	82	20	4.0
S00069230	129	283	0.5

The majority of the shoreline surrounding northern Loch Spelve is uninhabited and inaccessible by road. The small settlement of Ardura is located at the north-western extent of the loch. The small settlement of Croggan is located to the south of the mussel fisheries. No tourist accommodation is thought to be present in the survey area. No settlements are located around the southwestern arm of the loch.

A slipway is located west of Ardura and a pier is located north of Site 3. Three anchorages are present, one west of Ardura, the second north of Site 3 and the third north of Castle Site (Clyde Cruising Club, 2007). The pier at Croggan is derelict.

The local population in the vicinity of the survey area is relatively low and concentrated at Ardura and Croggan, Site 3, Ardura Site and Castle Site are likely to be more impacted by human-related sources due to the presence nearby of dwellings at Ardura and the boating activity at the pier, slipway and anchorage. There may be some impact from Croggan at the Killean site if currents flow northwards across the inner part of the entrance channel under some conditions.

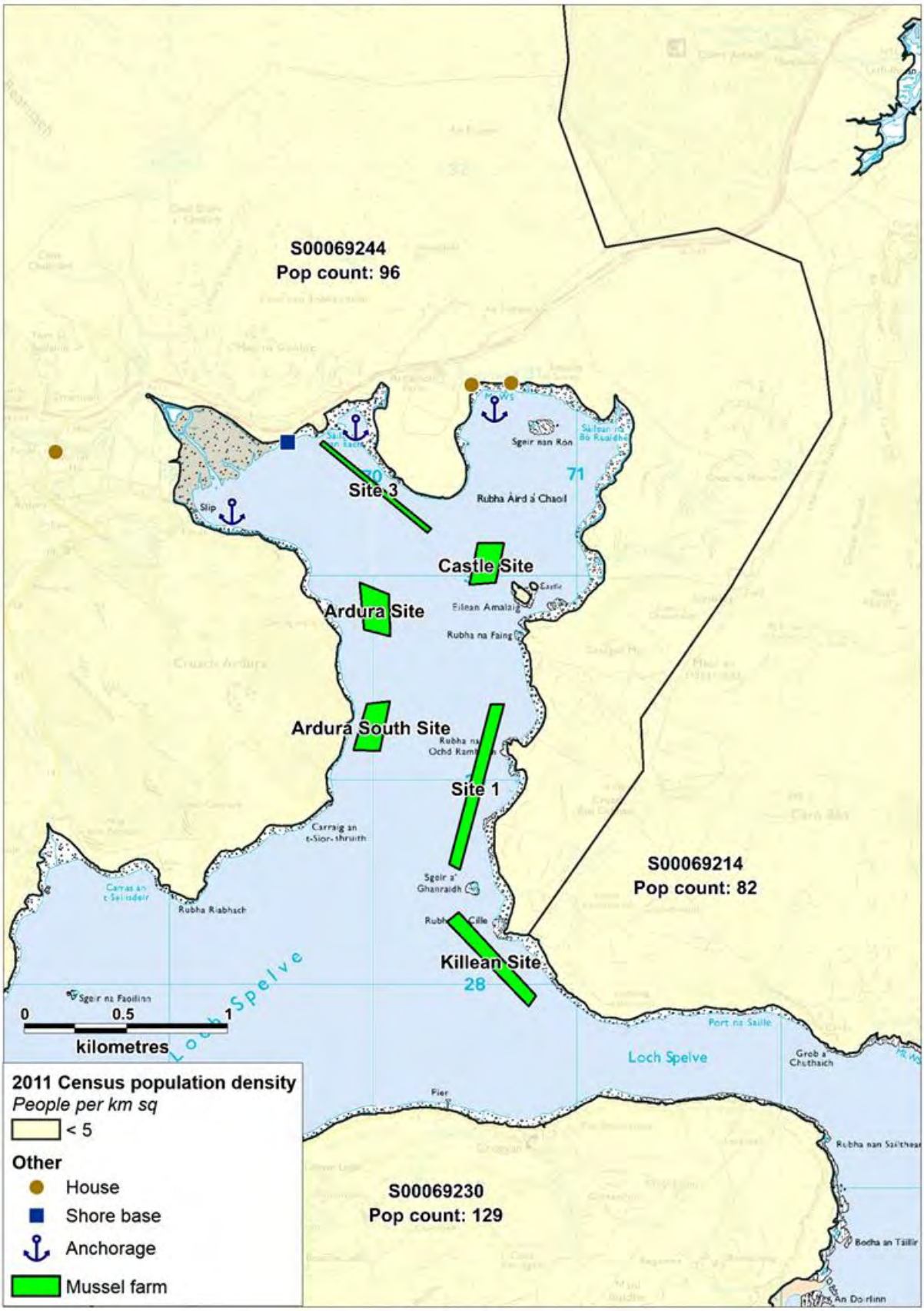


Figure 3.1 Population map for the area around the eastern Loch Spelve

4. Sewage Discharges

Information on sewage discharges within an area 5.5 km around the point NM 7039 2833 (the RMP location for Loch Spelve: Rubha na Faing) 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 provided information on one community sewage works; however this discharges to an adjacent loch and is unlikely to have an impact on water quality within Loch Spelve . It has therefore been excluded from this assessment. SEPA did not provided any information on community discharges within the request area.

4.2 Consented Private Discharges - SEPA

SEPA provided information regarding 11 consented private sewage discharges within the request area identified. Of these, eight were located around Loch Spelve. The remaining consents related to private discharges located around adjacent water bodies. These were considered unlikely to have a direct impact on the fishery due to their small size and were therefore excluded from assessment. A summary of the assessed discharges is given in Table 4.1 and the locations given are shown in Figure 4.1. Registration of sewage discharge is required for all new properties and upon sale of existing properties. Information provided by SEPA is considered to be correct at the time of writing; however there may be additional discharges that are not yet registered with SEPA.

Table 4.1 Private discharge consents around Loch Spelve

Licence Number	National Grid Reference	Discharge Type	Discharging to	PE
CAR/R/1020737	NM 68377 30507	Sewage (Private) Primary	U/T of Lussa River	15
CAR/R/1032068	NM 69070 31090	Sewage (Private) Primary	Soakaway	5
CAR/R/1037898	NM 70887 27211	Sewage (Private) Primary	Soakaway	5
CAR/R/1117297	NM 68332 28640	Sewage (Private) Secondary	UN/WC	12
CAR/R/1117298	NM 68340 28700	Sewage (Private) Primary	Soakaway	12
CAR/R/1120209	NM 68418 28755	Sewage (Private) Secondary	U/T of Loch Spelve	0
CAR/R/1124126	NM 65775 25573	Sewage (Private) Primary	Allt a Chonnaidh	6
CAR/R/1124653	NM 65770 25601	Sewage (Private) Primary	Allt a Chonnaidh	5

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

Information on locations where sewage sludge is applied to land had been requested from SEPA: it was identified that little data was held on this and that the data that was held could not be made available for assessment within the sanitary survey programme.

SEPA provided consents relating to two marine cage fish farms (MCFF) within the area requested. Working facilities on these may have toilets and sewage facilities, but no information of any were given.

4.3 Shoreline Survey Discharge Observations

No observations of sewage discharges or infrastructure were observed during the 2014 shoreline survey.

Information from the Loch Spelve – Croggan Pier sanitary survey report from 2012 identified that two small private septic tanks were observed on the southern shore of the inner entrance channel around Croggan. One discharged to land, the other to a culvert.

4.4 Summary

Sewage discharges to Loch Spelve are limited to small private discharges.

Of the eight septic tank discharges identified from SEPA records, six of these, including the three with the highest consented PE values, are located towards the northern end of the loch within 2 km of the fishery.

The discharge with the largest consented PE (CAR/R/1020737) has discharges to River Lussa. There are likely to be additional discharges at Ardura. Sources at that location will potentially impact the mussel sites at the northern three mussel sites while the discharges at Seanvaile will potentially affect the southern ends of the southernmost mussel sites. Actual impacts will be dependent on transport distance as well as dilution and dispersion. Discharges located at Croggan could potentially impact at the Killean site but this would depend on whether currents flow northward across that end of the entrance channel under certain conditions.

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

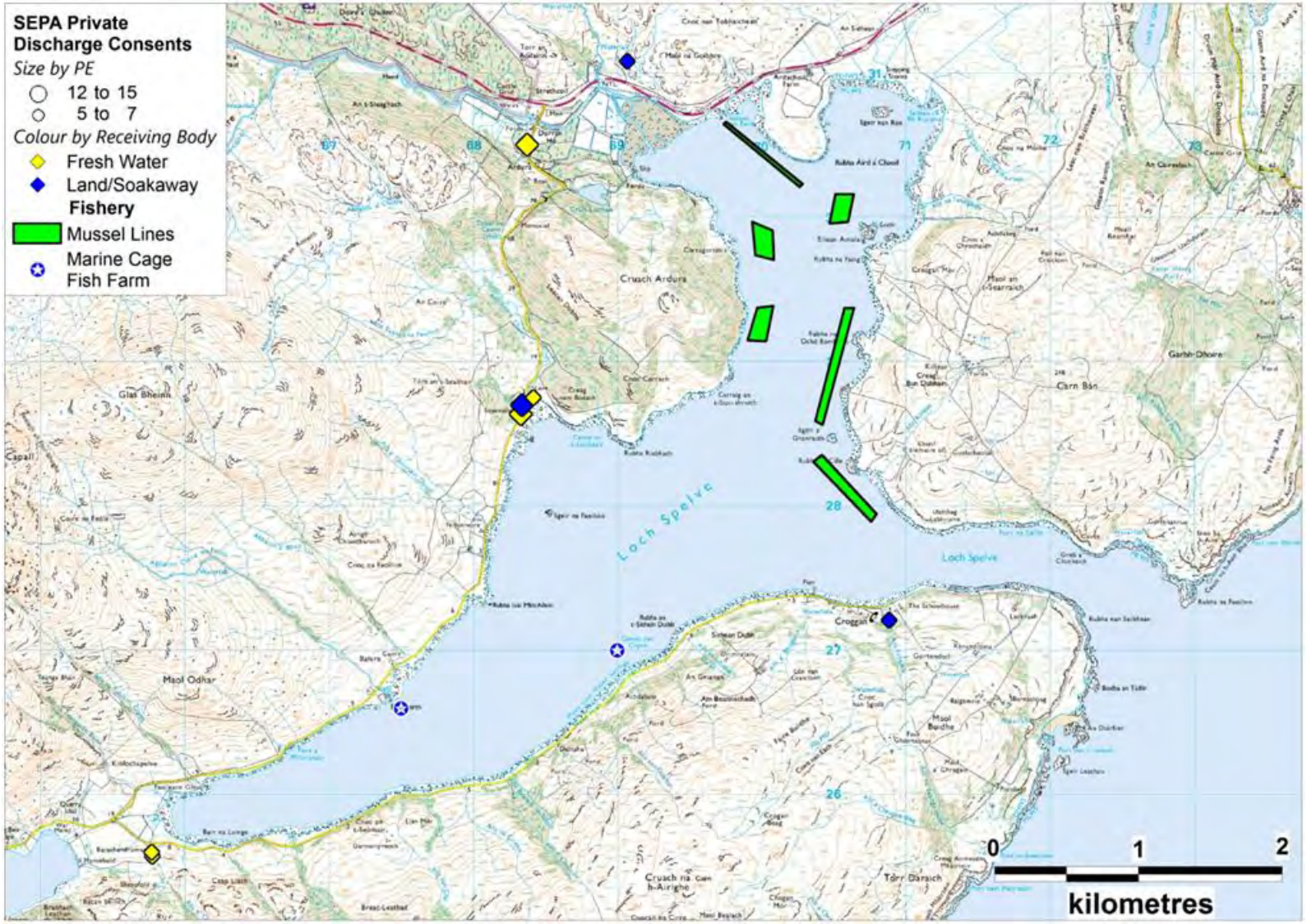


Figure 4.1 Map of discharges for Loch Spelve: Inverlussa and Rubha na Faing

5. Agriculture

Information on the spatial distribution of animals on land adjacent to or near the shellfisheries can provide an indication of the potential amount of organic pollution from livestock entering the shellfish farm areas. Agricultural census data to parish level was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for the Torosay 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 Torosay agricultural parish

	Torosay	
	367 km^2	
	Holdings	Numbers
Pigs	*	*
Poultry	8	210
Cattle	12	776
Sheep	14	11794
Horses used in Agriculture	0	-
Other horses and ponies	7	20

* data withheld

The livestock census numbers for Torosay relate to a large area, covering the south east section of the Isle of Mull. Therefore it is not possible to determine the spatial distribution of the livestock on the shoreline adjacent to the survey area or to identify how many animals are likely to impact the catchment around the shellfish farms. Although the figures are of little use in assessing the potential impact of livestock contamination to the shellfisheries they do give an idea of the total numbers of livestock over the broader area. Sheep were kept in moderate numbers in the parish while poultry and cattle were keep in small numbers. Pig numbers were not reported due to the small number of holdings present and no horses used in agriculture were reported.

A source of spatially relevant information on livestock population in the area was the shoreline survey (see Appendix 5) which only relates to the time of the site visit on the 22nd – 23rd September 2014. Observations made during the survey are dependent upon the viewpoint of the observer and some animals may have been obscured by the terrain. A total of thirty-four sheep and three cows were observed in the vicinity of Ardura with five of the sheep being on the shorelineNorth of the loch adjacent to Ardachoil farm, Two cows and cattle faeces were noted adjacent to Ardachoil farm at the northern end of the loch . Cattle faeces were also present on the shoreline to the east of the Castle mussel site.

The Ardura-Auchnacraig SSSI report (Scottish Natural Heritage, 2012) states part of the designation is under the Woodland Grant Scheme and that, as a result, all livestock have been removed from the Cruach area (on the western side of the loch).

Livestock were seen around Croggan during the shoreline survey undertaken there in 2011. A large number of sheep had been gathered in a small field near one of the houses, and both sheep and cattle appeared to have had access to the shoreline. Most of the droppings and a small number of sheep were seen to the east of Croggan, nearer to the mouth of the loch.

A review of publicly available aerial images shows that areas of improved pasture are located along the coastline of Loch Spelve, including on the coast adjacent to Ardura and the Site 3 shellfish farm (Bing Maps, accessed 09/12/2014 (imaging date Apr-May 2012, http://mvexel.dev.openstreetmap.org/bing/). Areas identified from the aerial images as likely improved pasture are shown in Figure 5.1. The 1:25,000 Ordnance Survey map identified Ardachoil farm and a sheepfold north of the loch and a cattle grid west of Ardura. SEPA identified a sheep dip on to land on the northern coastline of the loch as shown in Figure 5.1.

Information on locations where animal slurry is stored and/or applied to land had been requested from SEPA: it was identified that little data was held on this and that the data that was held could not be made available for assessment within the sanitary survey programme.

Numbers of sheep are expected to be approximately double during the spring and summer months when lambs are present.

Conclusions

Any contributions of faecal contamination from livestock are expected to be low to moderate, with the greatest impact on the mussel sites at the northern end of the loch, primarily Site 3 and Ardura but potentially also the Castle site.

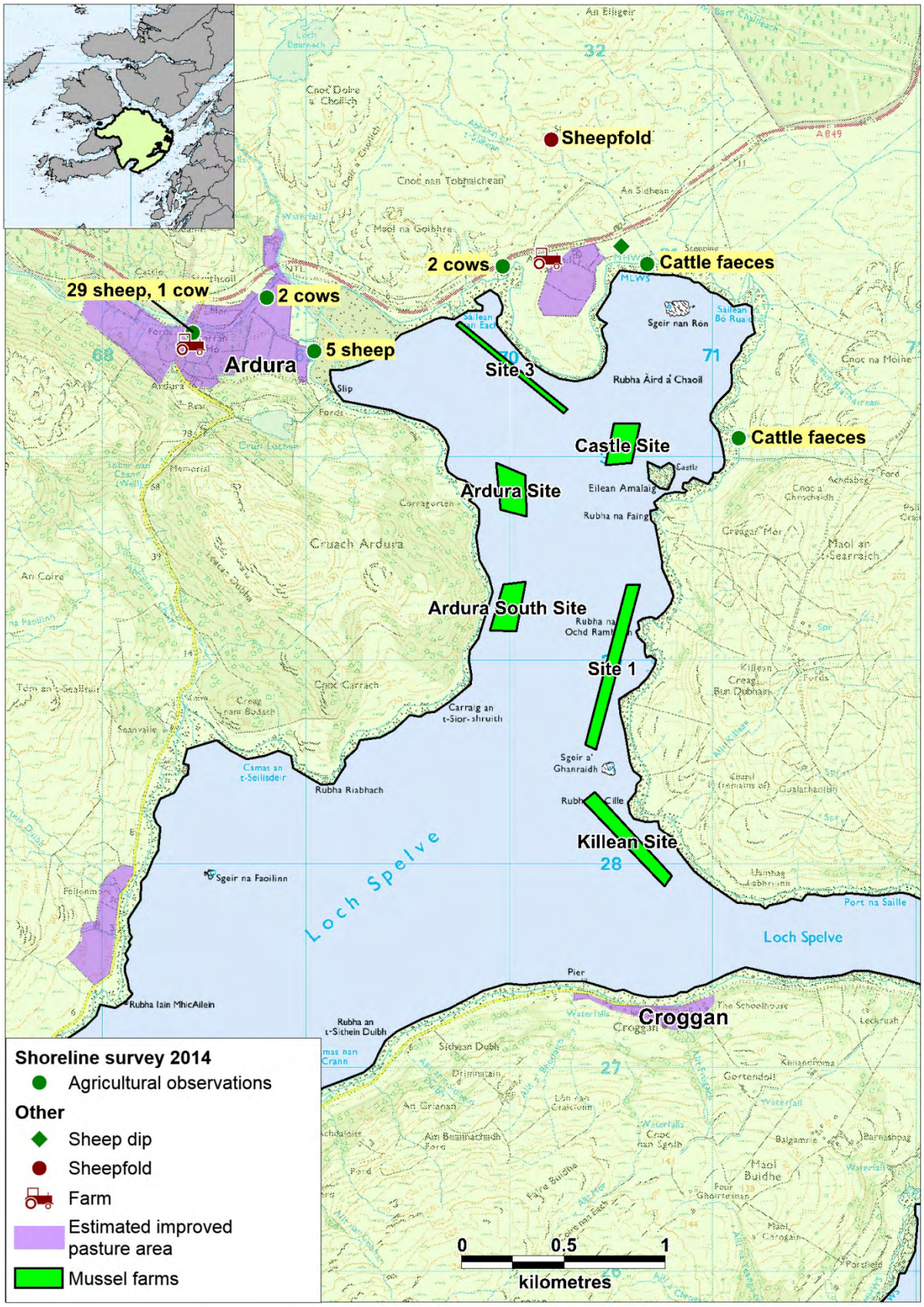


Figure 5.1 Livestock observations at Loch Spelve

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 spatially 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 runoff or watercourses.

The species for which information was potentially available and which could contribute to faecal indicator levels at Loch Spelve are considered below.

Pinnipeds

The Special Committee on Seals report stated that, overall, the west of Scotland common seal population is stable, with a total of 10,611 seals noted in 2009 (Special Committee on Seals, 2013). It identified that both common and grey seals are found around the Isle of Mull. However, no sightings of seals were reported within Loch Spelve. Four adult common seals and one pup were observed during the shoreline survey. Three adults and the pup were seen hauled out on rocks adjacent to Site One. This suggests the area is either a pupping ground or close to one. The other adult seal was noted west of Eilean Amalaig Island, close to Site One and the Killean site.

Cetaceans

Six common dolphins (four sightings), two harbour porpoise and 30 bottlenose dolphins have been reported in the Loch Spelve channel (Hebridean Whale and Dolphin Trust, 2014). The waters around the Isle of Mull are recognised as being a good place to see minke whales, killer whales, common dolphins, Risso's dolphins, bottlenose dolphins and harbour porpoise (Explore Mull, 2011). No cetaceans were observed during the shoreline survey.

Seabirds

Seabird data was downloaded from the collated JNCC dataset from the website (JNCC, 2014) in March 2014. The most recent datasets were extracted where repeat counts were available for the same locations. 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.

The JNCC reports all relate to Loch Don which is located approximately 4 km northeast of Loch Spelve.

Table 6.1 Seabird counts within 5 km of Loch Spelve

Common name	Species name	Count	Method	Accuracy
Black-Headed Gull	*Chroicocephalus ridibundus*	1	Occupied nests	Estimate
Herring Gull	*Larus argentatus*	30	Occupied nests	Estimate
Common Gull	*Larus canus*	19	Occupied nests	Unknown
Arctic Tern	*Sterna paradisaea*	1	Occupied territory	Accurate

Anecdotal information suggests however that the area surrounding Loch Spelve supports a large number of bird species. They include waterfowl in the winter months, particularly in the sheltered southwest end of the loch. During the summer, waders and other small birds nest along the shoreline. Furthermore, seabirds such as razorbill, common and black guillemots use the area to feed (Wild Future, 2014).

Birds were the most abundant wildlife noted during the shoreline survey. Common and herring gulls were present in the greatest numbers, with 100-200 noted on the mussel buoys and in the waters around the Castle site. Of these birds, 80% appeared to be juvenile suggesting that this area is, or is close to, a nesting/breeding area. Four mute swans were noted feeding on mussels at the Ardura South site and nine cormorants were noted in the water and on mussel lines at the Killean site. Greylag geese were seen along the shoreline to the north, where goose faeces were also observed. Other species included herons, rock pipits, crows, a white tailed eagle, a snipe and a curlew.

Otters

The Isle of Mull is known to have a healthy population of the Eurasian otter (*Lutra lutra*) (Explore Mull, 2014). In particular, otters may be found along much of the shoreline in Loch Spelve (Wild Future, 2014). No otters were observed during the shoreline survey.

Deer

It is expected that approximately 6,000 red deer are located on the Isle of Mull (Explore Mull, 2014). Dense Ardura woodland to the northwest of Loch Spelve is known to host a population of red deer, which are also stalked for sport within the Ardura Estate to the northwest of Loch Spelve (Scottish Natural Heritage, 2012). No deer were observed during the shoreline survey.

Conclusions

Overall, seabirds are expected to be the most significant contributory sources to wildlife based faecal contamination inputs. In particular it is thought that common and herring gulls will contribute significantly to contamination levels. Other species likely to contribute include geese and cormorants. The available information indicates that any effect may be greatest at the northeastern end of the loch. Seals and cetaceans may also contribute to contamination levels within the loch.

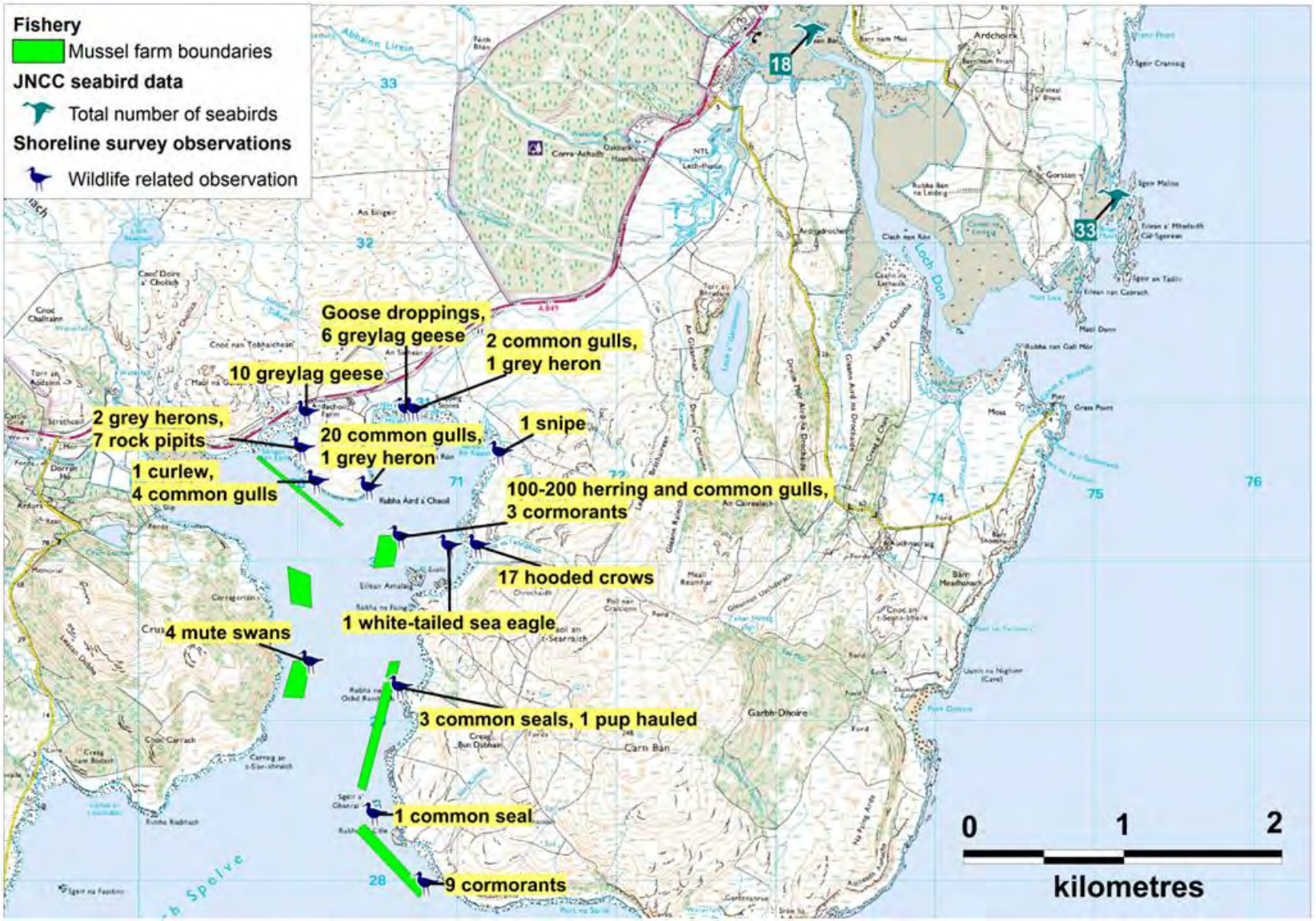


Figure 6.1 Map of wildlife around the northern end of Loch Spelve

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. The predominant land cover types adjacent to the shellfish farms are broad leaved woodland, rough grassland, dwarf shrub heath and improved grassland. There are also scattered areas of bog, acid grassland and coniferous woodland. Improved grassland is located inland from the shorelines east of the Killean and Castle sites, west of Site 3 around Ardura, and at Croggan, south of the Killean site.

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

The highest potential contribution of contaminated run-off to the mussel farms is from the areas of improved grassland located on the shorelines adjacent to the fisheries. Any impact is likely to be greatest on long lines situated closest to the shoreline: in this regard, the Killean site is closest to areas of improved grassland. This contribution would be expected to increase after rainfall events.

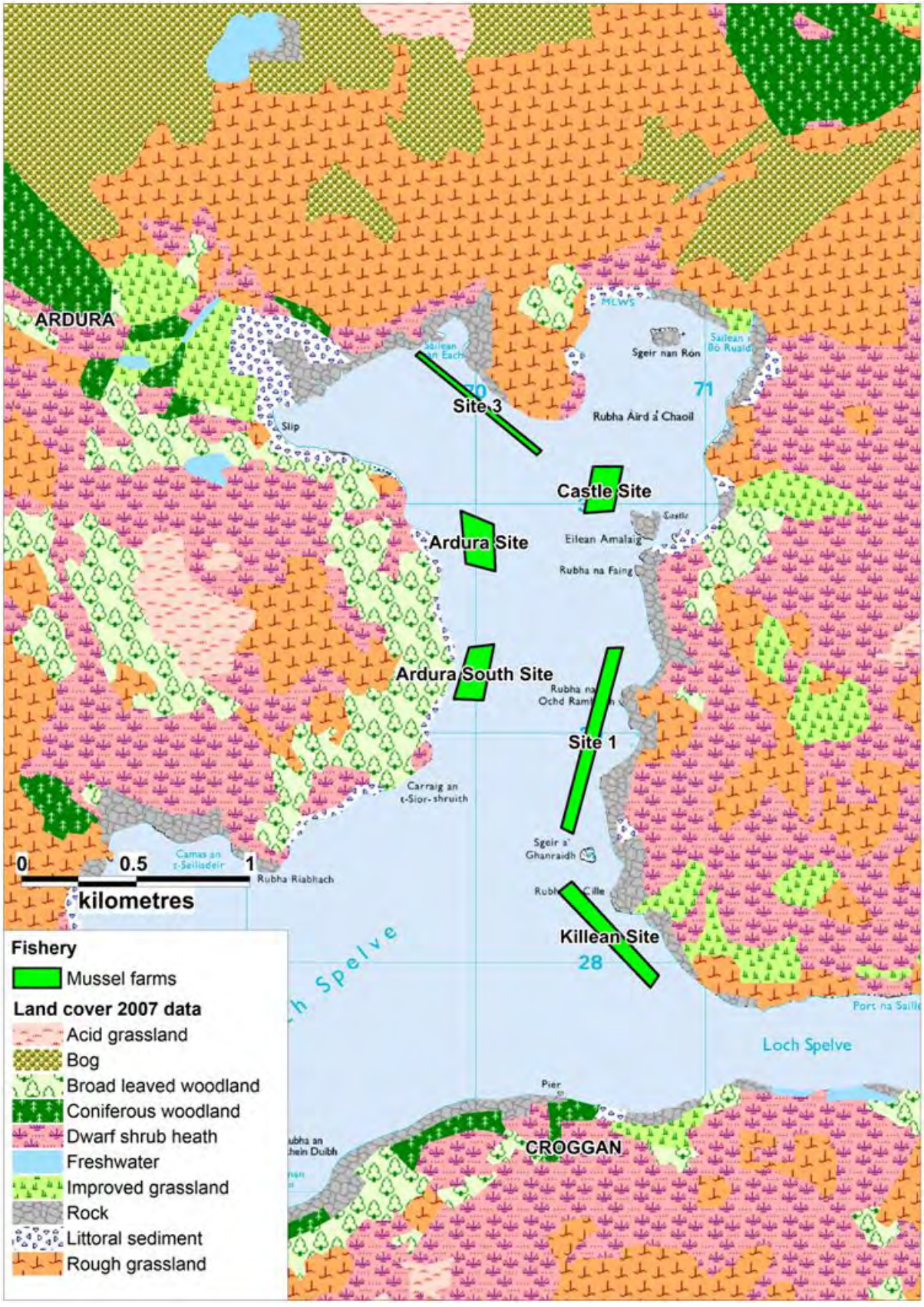


Figure 7.1 LCM2007 land cover data for the area around the northern end of Loch Spelve

8. Watercourses

There are no gauging stations on watercourses entering Loch Spelve.

Spot measurements of flow and microbial content were obtained during the shoreline survey conducted on the 22nd – 23rd September 2014. No rain was recorded in the 48 hrs prior to the survey. The watercourses listed in Table 8.1 are those recorded during the shoreline survey. The locations and loadings of measured watercourses are shown in Figure 8.1.

Table 8.1 Watercourses entering Loch Spelve

No.	Eastings	Northings	Description	Width (m)	Depth (m)	Flow (m^3/d)	Loading (*E. coli* per day)
1	169259	730181	Unnamed watercourse	1.36	0.12	113	$<1.1 \times 10^7$
2	169102	730271	Unnamed watercourse	0.73	0.08	141	2.8×10^7
3	168966	730621	Dried up stream bed				
4	168935	730765	Dried up stream bed				
5	168886	730887	Lussa River	11.81	0.38	51800	5.2×10^{10}
6	170481	730944	Unnamed watercourse	0.85	0.12	53	5.0×10^6
7	170731	730954	Abhainn an t-Sidhean	1.83	0.29	2610	2.4×10^9
8	170856	730958	Feith Bhan	6.74	0.07	3020	3.3×10^9
9	171196	730869	Unnamed watercourse	1.21	0.05	387	4.3×10^8
10	171288	730741	Unnamed watercourse - stagnant	Not measured or sampled			Not determined
11	171267	730682	Allt Leac nam Brathairean	Not measured or sampled			Not determined
12	171138	730065	Allt na Teangaidh	1.05	0.14	64	$<6.0 \times 10^6$
13	171134	729984	Unnamed watercourse	Not measured or sampled			Not determined
14	170795	728202	Allt Killean	0.76	0.07	818	3.5×10^9

Several small watercourses were observed located along the coastline in the vicinity of the shellfish farms at the northern end of Loch Spelve. Watercourses numbered 3 and 4 were dry at the time of the survey. Watercourse number 10 was stagnant and not flowing and watercourses 11 and 13 were deemed not large enough to sample or measure. The Lussa River, approximately 800 m west of Site 3 at the northwestern end of the loch, had the highest estimated *E. coli* loading of 5.2×10^{10}. Allt Killean enters the loch approximately 160 m north east of the Killean Site: this watercourse had the second highest estimated loading at 3.5×10^9. The remaining seven watercourses had low to moderate estimated *E. coli* loadings.

Overall, freshwater inputs would be expected to provide higher levels of contamination to the mussel farms at the northern end of the loch (Site 3, Ardura Site and Castle Site) and also to the Killean Site with the highest impact expected from the watercourses that discharge directly adjacent to the shellfish farms.

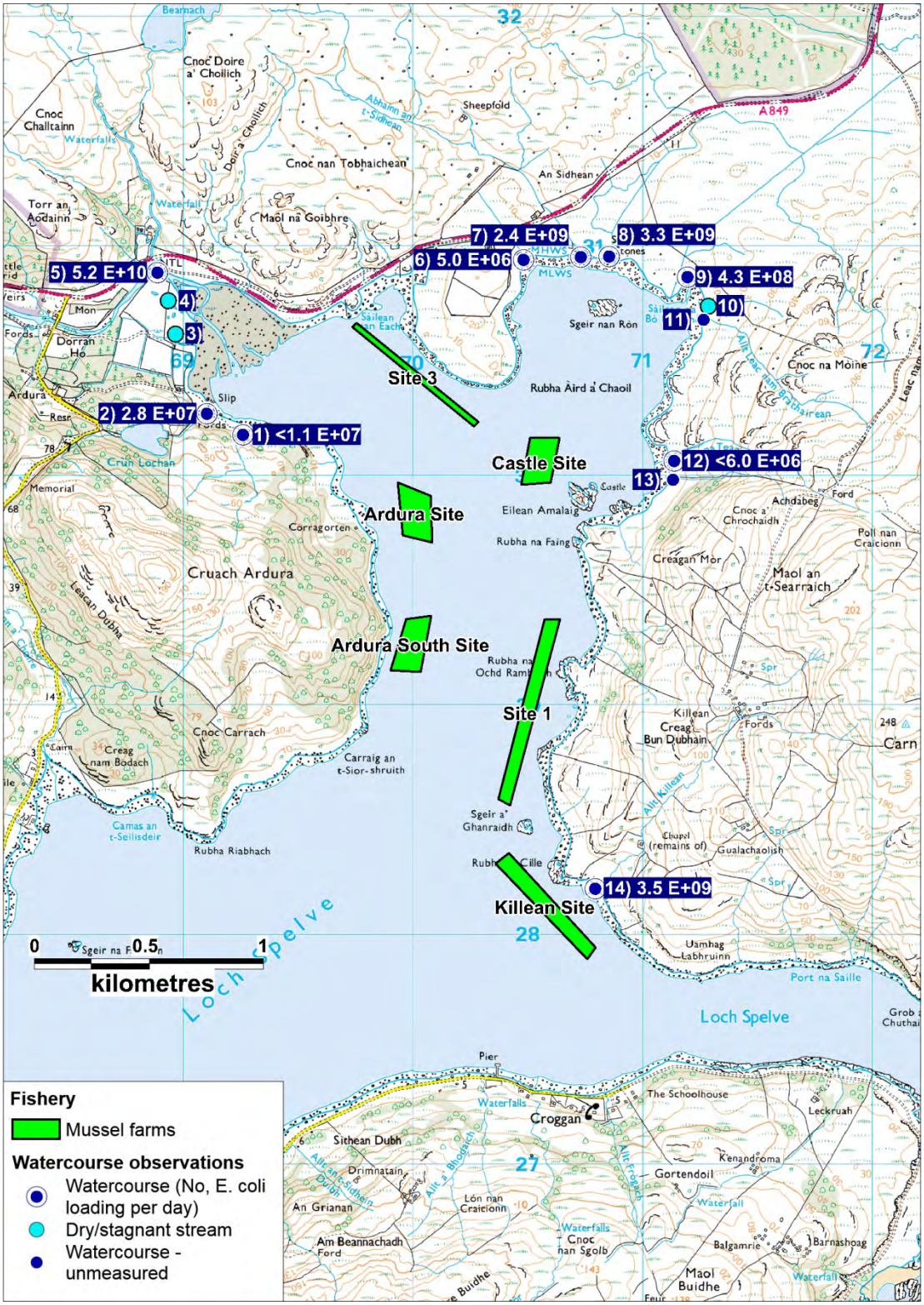


Figure 8.1 Map of watercourse loadings at Loch Spelve

Where the bacterial loading is labelled on the map, the scientific notation is written in digital format, as this is the only format recognised by the mapping software. So, where normal scientific notation for 1000 is $1x10^3$, in digital format it is written as 1E+03.

9. Meteorological Data

The nearest weather station for which a largely complete rainfall data set was available is located at Lismore; Frackersaig Farm, situated approximately 20 km to the north-west of the production area. Rainfall data was available for January 2008 – November 2013. Data was not available for December 2013. Several other dates were excluded during data validation as they were estimated or aggregated.

The dates excluded were: 11–14/01/2008, 31/03/2008, 01/04/2008, 04–05/06/2008, 16–19/06/2008, 04–05/05/2009, 17–18/05/2009, 10–11/08/2009, 01–02/12/2010, 16–22/08/2011, 29–30/10/2011, 22–23/08/2012, 04–05/12/2012.

The nearest wind station is situated in Tiree, located 72 km west of the production area. Conditions may differ between this station and the mussel farms due to the distances between them. However, this data is still shown, as it can be useful in identifying seasonal variation in wind patterns.

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

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 th-e 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 *.

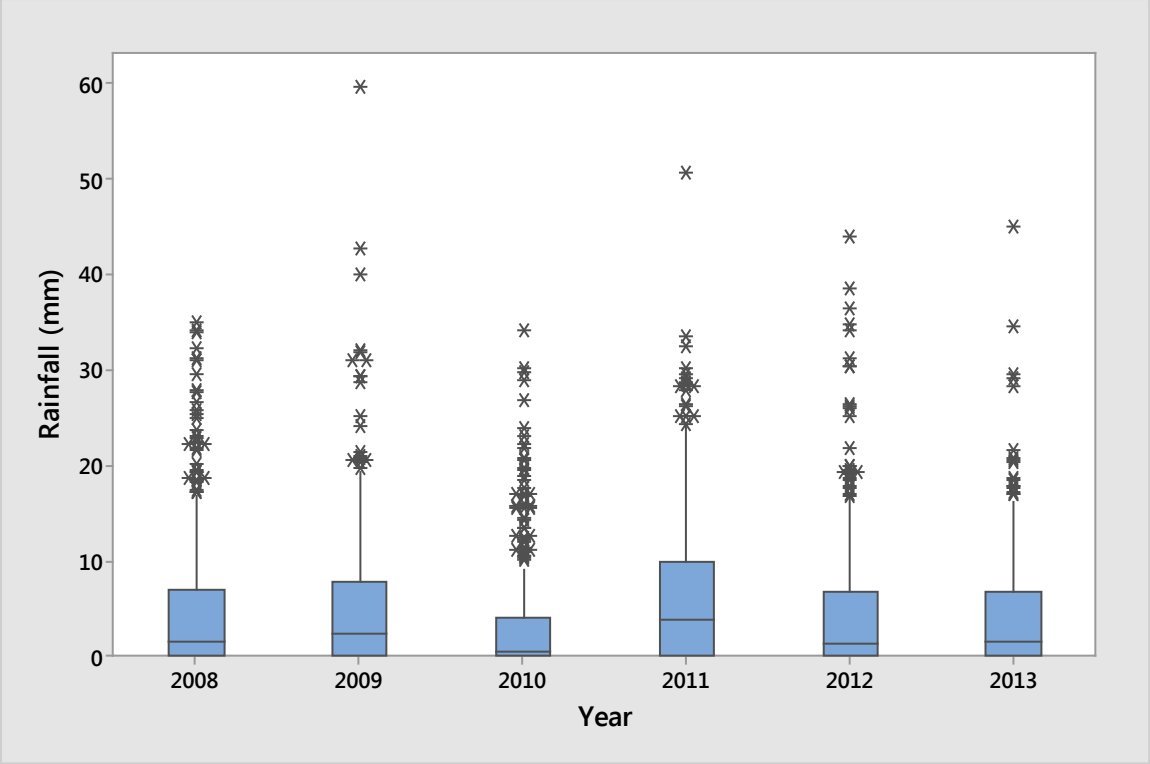


Figure 9.1 Box plot of daily rainfall values by year at Lismore; Frackersaig Farm (2008 – 2013)

Daily rainfall values varied from year to year, with 2010 being the driest year (1199 mm). The wettest year was 2011 (2354 mm). Rainfall exceeding 30 mm per day occurred in all years and exceptional rainfall values exceeding 40 mm/d occurred in 2009 and 2011-2013.

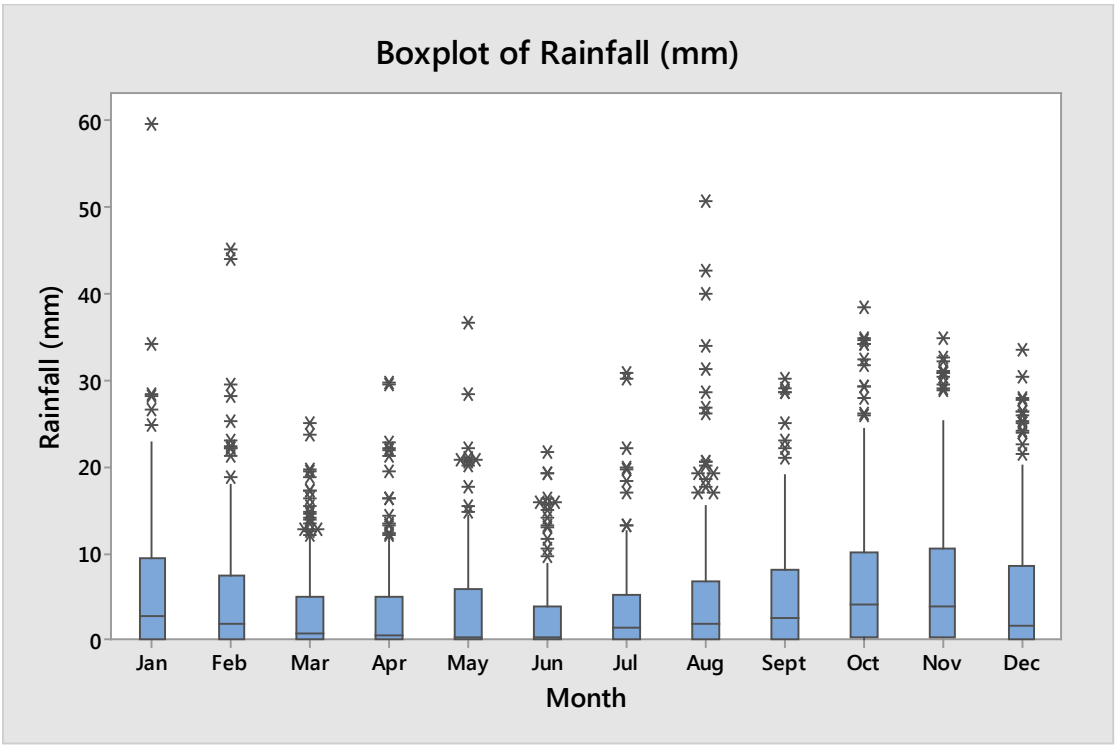


Figure 9.2 Box plot of daily rainfall values by month at Lismore; Frackersaig Farm (2008 – 2013)

Daily rainfall values were higher during the autumn and winter. Monthly rainfall totals increased from August, peaking in October (1348 mm). Weather was driest in June (429 mm). Rainfall values exceeding 30 mm/d were recorded in all months except March, April and June.

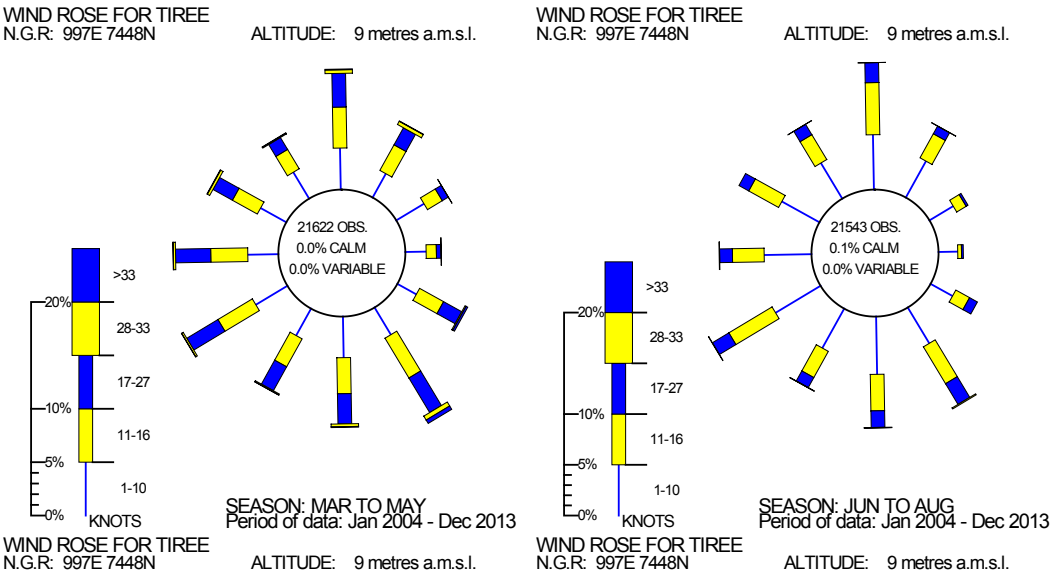
For the period considered here (2008 – 2013) 47 % of days received daily rainfall of less than 1 mm and 17 % of days received daily rainfall of over 10 mm.

It should be noted that the dates for which no rainfall data was available, or for which data were excluded from the assessment, will bias the values for the relevant years or months.

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.

9.1 Wind

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



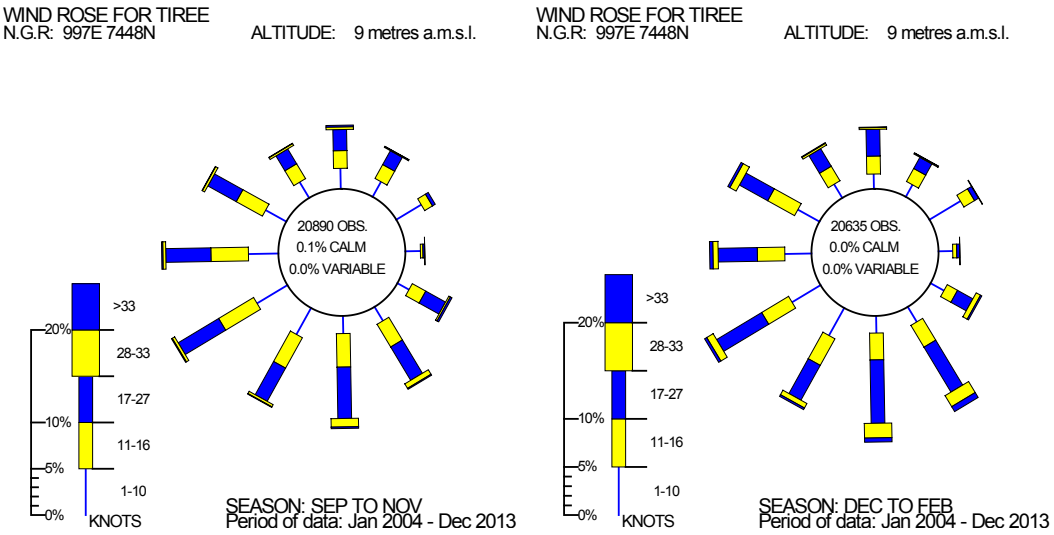


Figure reproduced under license from Meteorological Office. Crown Copyright 2012.

Figure 9.3 Seasonal wind roses for Tiree

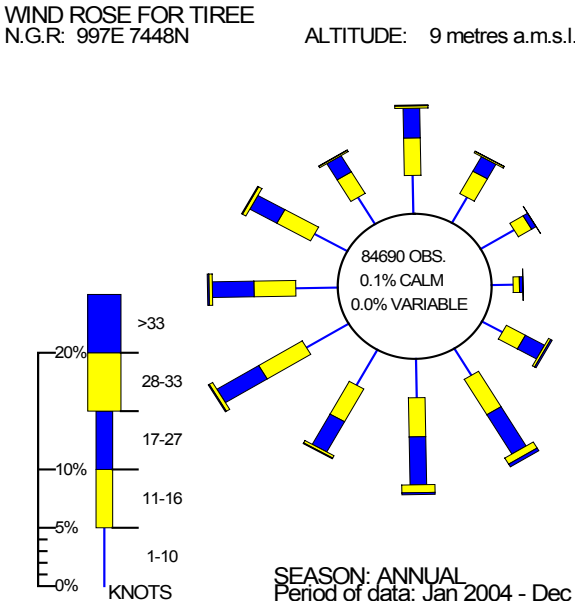


Figure reproduced under license from Meteorological Office. Crown Copyright 2012.

Figure 9.4 Annual wind rose for Tiree

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

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 Spelve: Inverlussa and Loch Spelve: Rubha na Faing are both classified for production of common mussels (Mytilus edulis). The classification histories since 2006 are listed in Table 10.1 and 10.2 below.

Table 10.1 Loch Spelve: Inverlussa 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	A	A	A	A	A	A	A	A
2008	A	A	A	A	A	A	A	A	A	A	A	A
2009	A	A	A	A	A	A	A	A	A	A	A	A
2010	A	A	A	A	A	A	A	A	A	A	A	A
2011	A	A	A	A	A	A	A	A	A	A	A	A
2012	A	A	A	A	A	A	A	A	A	A	A	A
2013	A	A	A	A	A	A	A	A	A	A	A	A
2014	A	A	A	A	A	A	A	A	A	A	A	A
2015	A	A	A									

Loch Spelve: Inverlussa was given a year round class A from 2006 to 2012 inclusive. In both 2013 and 2014, it received a split classification, with B months in the latter half of the year (although the number of months differed between the two years).

Table 10.2 Loch Spelve: Rubha na Faing 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	A	A	A	A	A	A	A	A
2008	A	A	A	A	A	A	A	A	A	A	A	A
2009	A	A	A	A	A	A	A	B	B	B	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									

Loch Spelve: Rubha na Faing has received a year round A classification apart from 2009 when it was given a B classification for the months of August to October.

11. Historical E. coli Data

11.1 Validation of historical data

Results for all samples assigned against Loch Spelve: Inverlussa and Loch Spelve: Rubha na Faing production areas for the period 01/01/2009 to the 28/11/2014 were extracted from the FSAS database on 28/11/2014 and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. All *E. coli* results were reported as most probable number (MPN) per 100 g of shellfish flesh and intravalvular fluid.

Thirty-seven Inverlussa sample results and 32 Rubha na Faing sample results reported as <18 or <20 were reassigned a value of 10 *E. coli* MPN/100 g for the purposes of statistical evaluation and graphical representation.

One sample assigned to Inverlussa and two samples from Rubha na Faing were identified as rejected and were omitted from further analysis in this report. One Inverlussa sample was received at the laboratory over 48 hours after collection and was also omitted from further analysis. The remaining sample results had box temperatures of ≤8^{o}C upon arrival and plotted within the production area boundaries.

11.2 Summary of microbiological results

Sampling and result summaries of results assigned to Inverlussa and Rubha na Faing between 2009 and 2014 are displayed in Table 11.1.

Regular sampling has taken place at both sites. Approximately half of the results from each production area were <20 *E.coli* MPN/100 g. No result from either area exceeded 1000 *E.coli* MPN/100 g.

Table 11.1 Summary of historical sampling and results

Sampling Summary		
Production area	Loch Spelve: Inverlussa	Loch Spelve: Rubha na Faing
Site	Inverlussa	Rubha na Faing
Species	Common mussel	Common mussel
SIN	AB-200-056-08	AB-202-059-08
Location	Various	Various
Total no of samples	70	69
No. 2009	12	11
No. 2010	12	12
No. 2011	11	11
No. 2012	12	12
No. 2013	12	12
No. 2014	11	11
Results Summary		
Minimum	<18	<18
Maximum	490	700
Median	<20	20
Geometric mean	20	24
90 percentile	108	130
95 percentile	154	235
No. exceeding 230/100g	1 (1%)	3 (4%)
No. exceeding 1000/100g	0	0
No. exceeding 4600/100g	0	0
No. exceeding 18000/100g	0	0

.

11.3 Overall geographical pattern of results

The reported geographical locations of all sample results assigned to Inverlussa and Rubha na Faing are shown in Figure 11.1. All sample locations were reported to 1 m accuracy. The symbol sizes are proportional to the magnitude of the corresponding *E. coli* result.

The majority of Inverlussa samples (n=66) were reported from a location between the southeast end of the mussel line (NM 70267 30206) and the nominal RMP (NM 7027 3018). The RMP location recorded during the shoreline survey lies approximately 26 m north of the nominal RMP, which is well within the 40 m sampling tolerance normally afforded long-line mussel farms.

Sampling at Rubha na Faing has occurred at the northeast end of the Killean site; the majority of samples (n=61) were reported to locations within approximately 10 m of the RMP. Eight samples from 2009 were reported from a separate location approximately 30 m southwest of the RMP.

Sampling had been undertaken on the same day at the two sites on sixty-seven occasions. A paired t-test on the log_{10}-transformed *E. coli* results for these dates showed no significant difference in mean log-transformed *E. coli* (T=1.44, p=0.155). However, the highest result was recorded at Rubha na Faing.

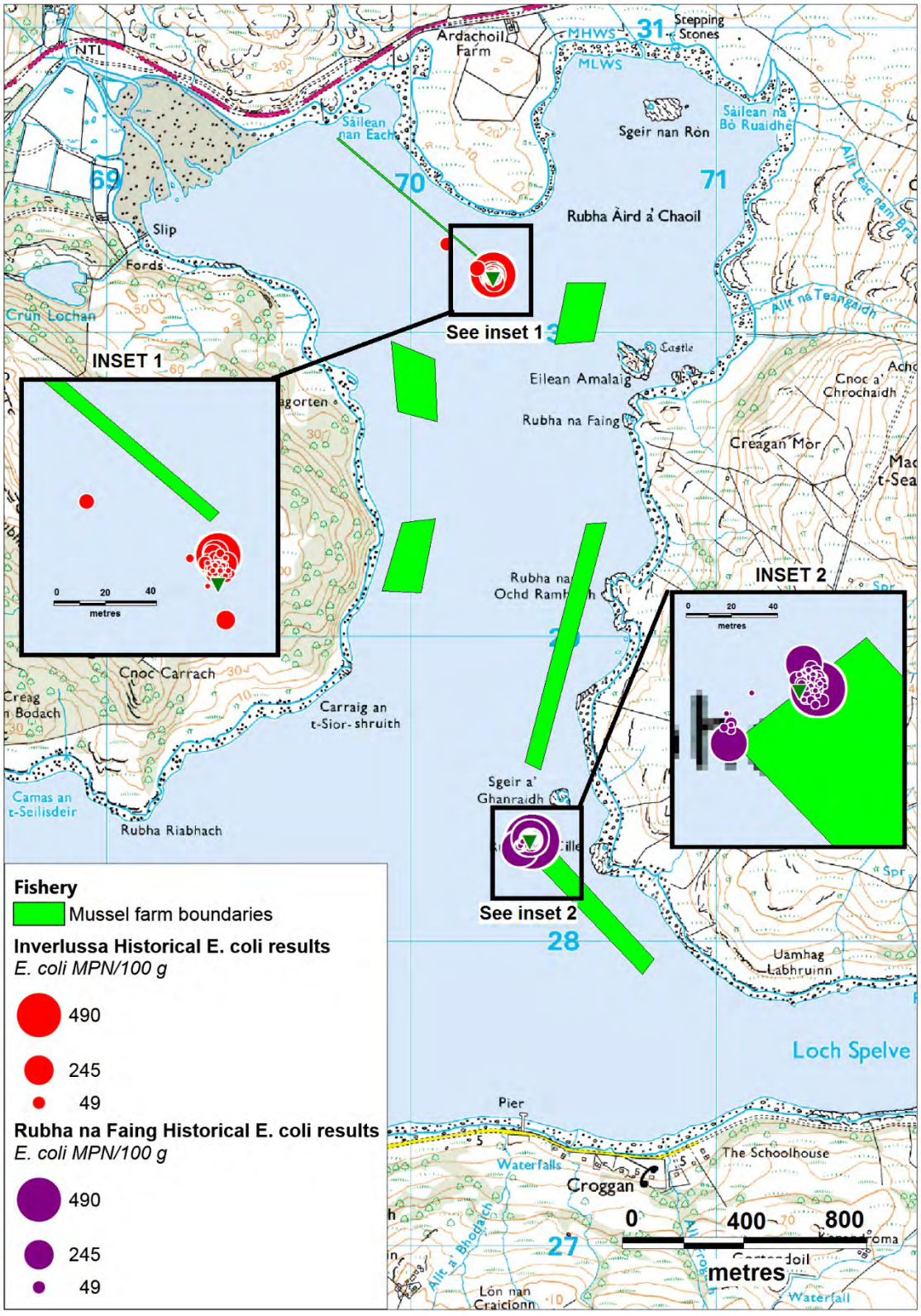


Figure 11.1 Historical sampling results at Inverlussa and Rubha na Faing

11.4 Overall temporal pattern of results

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

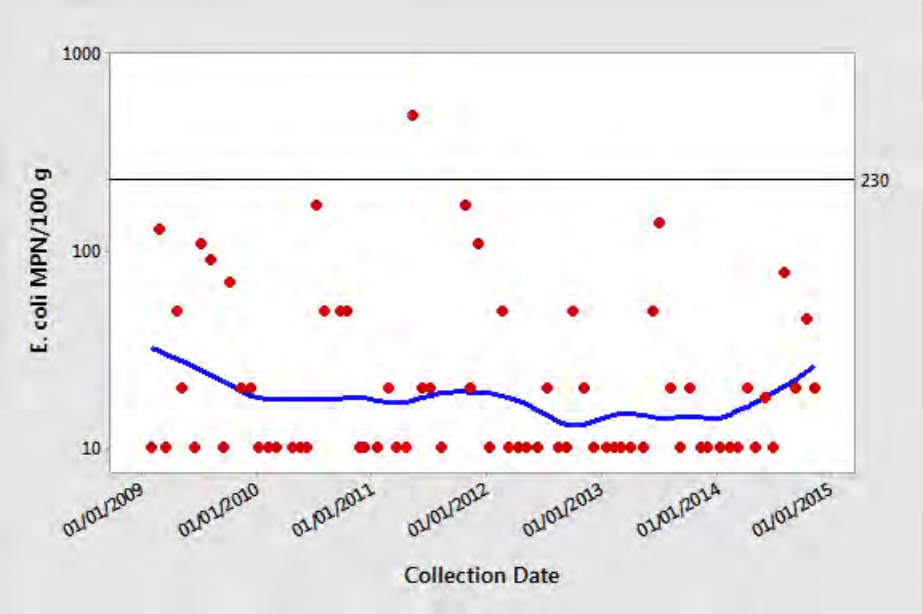


Figure 11.2 Scatterplot of E. coli results by collection date at Inverlussa

Results have remained constant at Inverlussa since 2009. The highest result was from a sample taken in 2011.

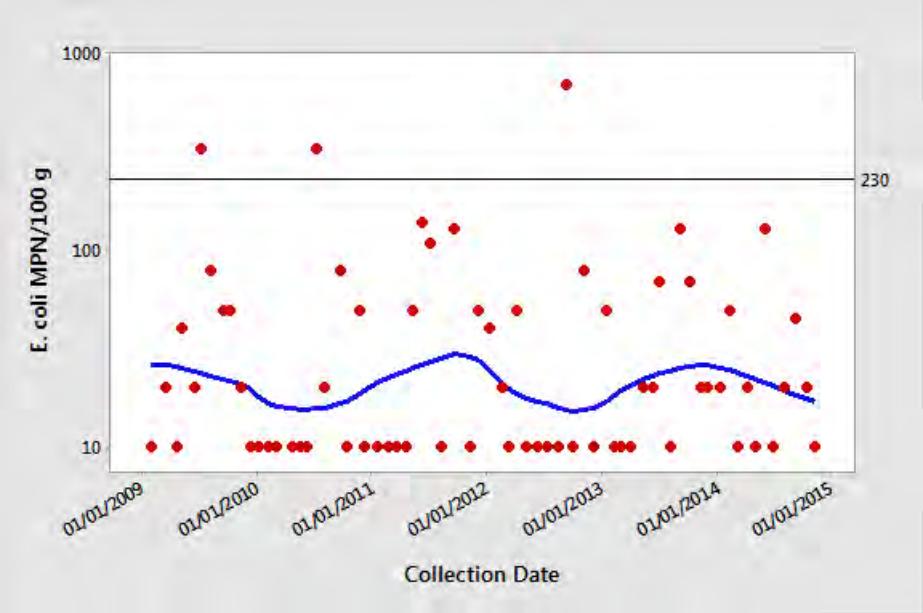


Figure 11.3 Scatterplot of E. coli results by collection date at Rubha na Faing

Monitoring results have largely remained constant at Rubha na Faing. The results exceeding 230 *E. coli* MPN/100 g occurred in 2009, 2010, and 2012.

11.5 Seasonal pattern of results

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

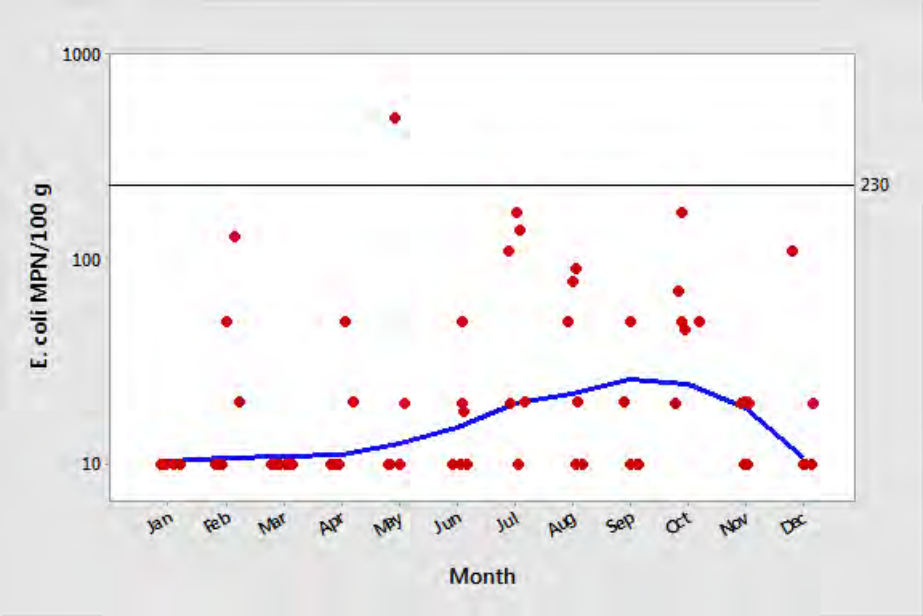


Figure 11.4 Scatterplot of E. coli results by month at Inverlussa

A slight increase in the trend line is apparent, peaking from August to October. The highest result occurred in May.

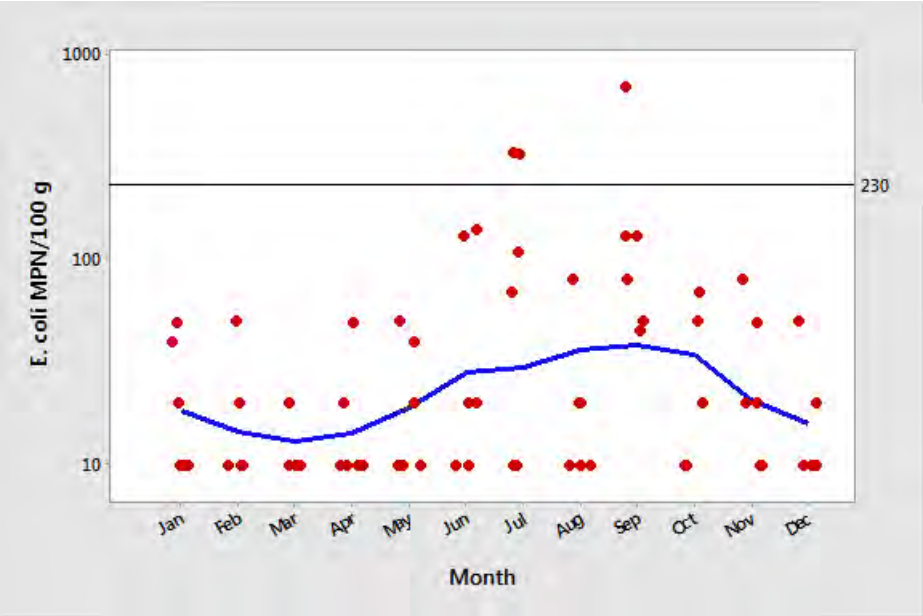


Figure 11.5 Scatterplot of E. coli results by month at Rubha na Faing

A slight increase in the trend line is apparent, with highest results occurring from June to September. The three highest results were from samples taken in July and September.

For statistical evaluation, seasons were split into spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). Boxplots of *E. coli* results by season for Inverlussa and Rubha na Faing are presented in Figures 11.6 and 11.7 respectively.

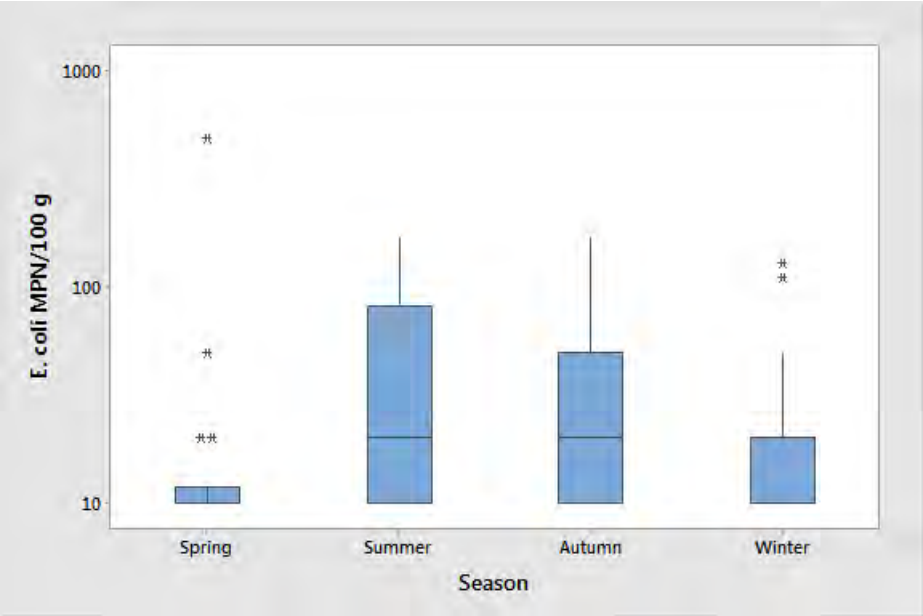


Figure 11.6 Boxplot of E. coli results by season at Inverlussa

No significant difference was found between *E. coli* results for Inverlussa by season (one-way ANOVA, p = 0.108) (Appendix 4).

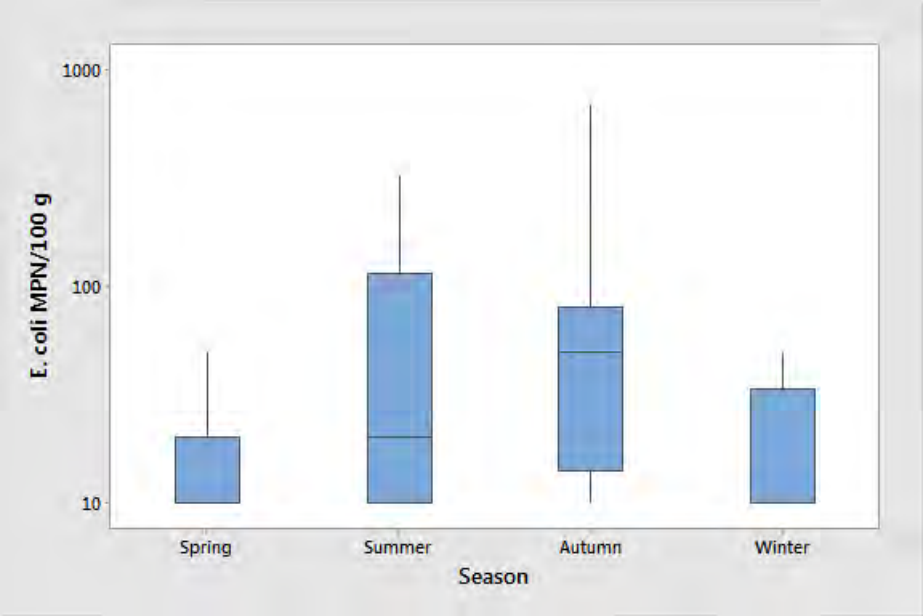


Figure 11.7 Boxplot of E. coli results by season at Rubha na Faing

A statistically significant difference was found between *E. coli* results for Rubha na Faing by season (one-way ANOVA, p = 0.006) (Appendix 4). Results were higher in autumn than in spring

11.6 Analysis of results against environmental factors

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

11.6.1 Analysis of results by recent rainfall

The nearest weather station with available rainfall data was at Lismore approximately 20 km northwest of Loch Spelve. Rainfall data was purchased from the Meteorological Office for the period of 01/01/09 - 31/11/2013 (total daily rainfall in mm).

Two-day rainfall

Scatterplots of *E. coli* results against total rainfall recorded on the two days prior to sampling for Inverlussa and Rubha na Faing are displayed in Figures 11.8 and 11.9 respectively. Rainfall data was available for 56 of the 70 Inverlussa sampling occasions and for 55 of the 69 Rubha na Faing sampling occasions. Jittering was applied at 0.02 (x-axis) and 0.001 (y-axis) respectively.

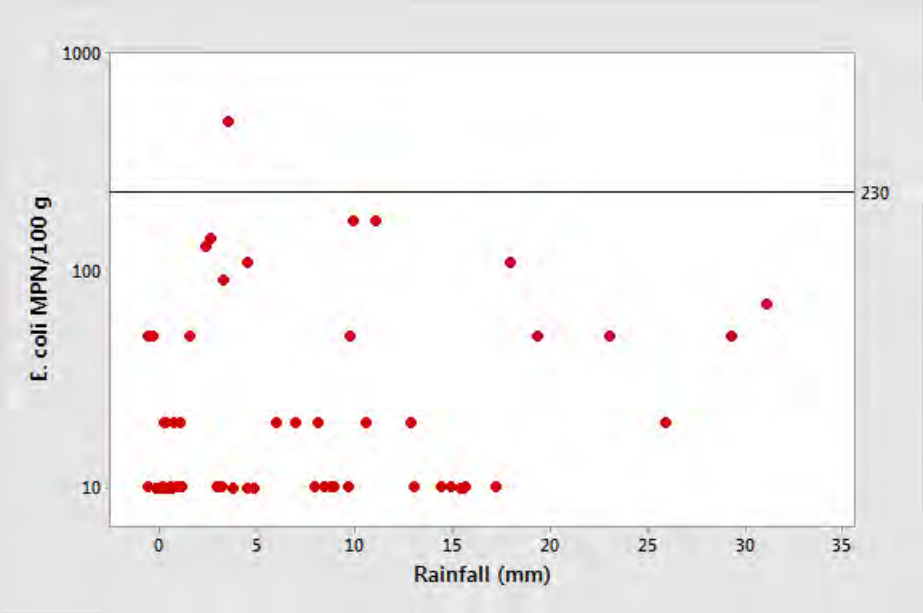


Figure 11.8 Scatterplot of E. coli results against rainfall in the previous two days at Inverlussa

No statistically significant correlation was found between Inverlussa *E. coli* results and rainfall during the two days prior to sampling (Spearman's rank correlation r = 0.181, p = 0.183). Results below 20 *E.coli* MPN/100 g mostly occurred at temperatures below 15°C. The highest result coincided with 2-day rainfall of less than 5 mm.

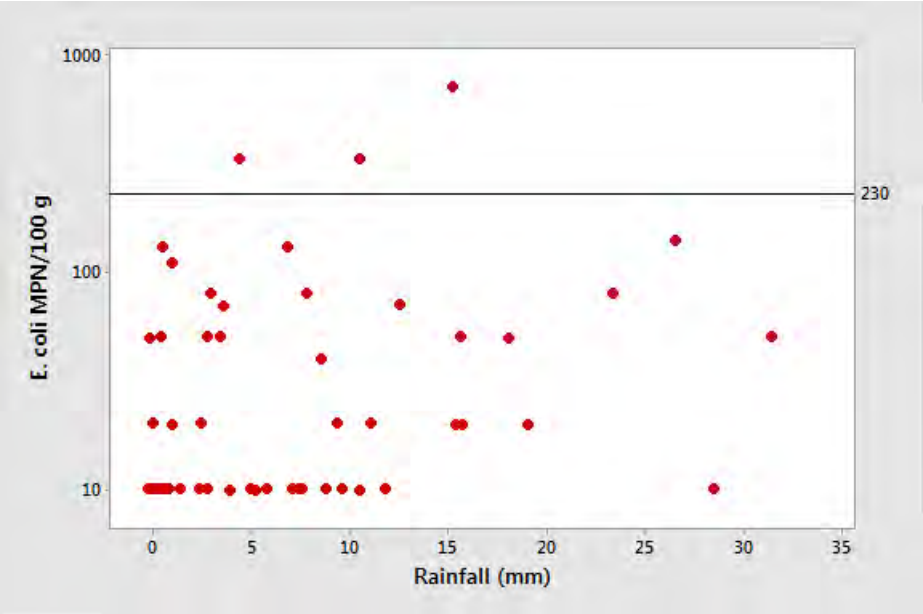


Figure 11.9 Scatterplot of E. coli results against rainfall in the previous two days at Rubha na Faing

A significant correlation was found between Rubha na Faing *E. coli* results and rainfall during the two days prior to sampling (Spearman's rank correlation r = 0.309, p = 0.022). Most results below 20 *E. coli* MPN/100 g were seen in samples taken at rainfall values exceeding 12 mm. However, the highest results all occurred after rainfall of less than 15 mm.

Seven-day rainfall

The effects of heavy rainfall may take differing amounts of time to be reflected in shellfish sample results in different systems. Therefore, the relationship between rainfall during the seven days prior to sampling and sample results was investigated in an identical manner to the above. Scatterplots of *E. coli* results against total rainfall recorded for the seven days prior to sampling at Inverlussa and Rubha na Faing are shown in Figures 11.10 and 11.11 respectively. Rainfall data was available for 55 of the 70 Inverlussa sampling occasions and 54 of the 69 Rubha na Faing sampling occasions. Jittering was applied at 0.02 (x-axis) and 0.001 (y-axis) respectively.

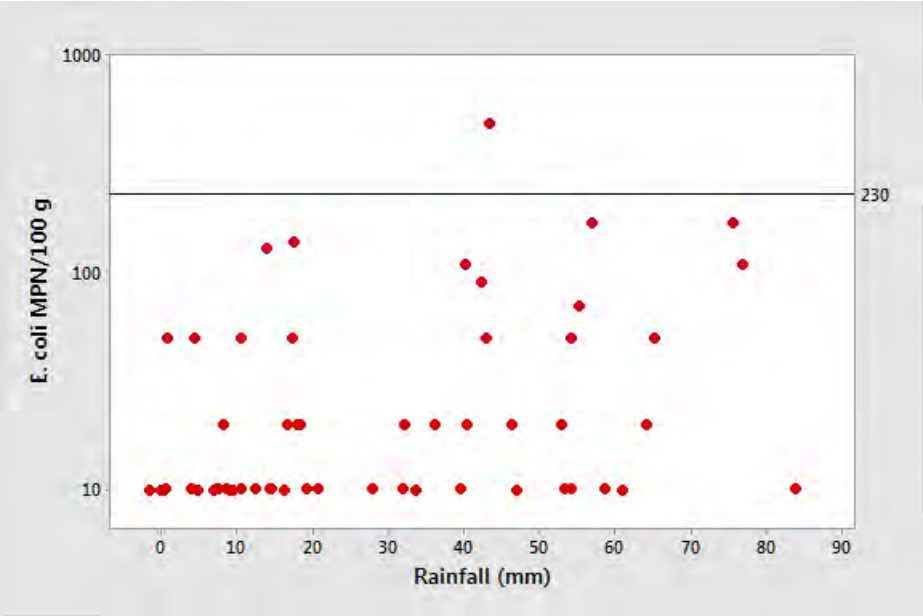


Figure 11.10 Scatterplot of E. coli results against rainfall in the previous seven days at Inverlussa

A highly significant correlation was found between Inverlussa *E. coli* results and the previous seven day rainfall (Spearman's rank correlation r = 0.361, p = 0.007).

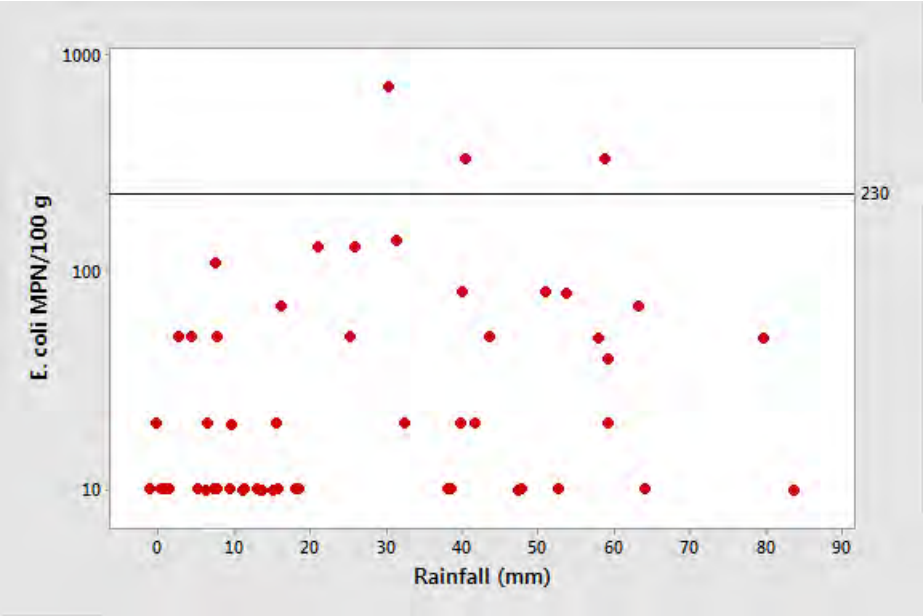


Figure 11.11 Scatterplot of E. coli results against rainfall in the previous seven days at Rubha na Faing

A significant correlation was found between Rubha na Faing *E. coli* results and the previous seven day rainfall (Spearman's rank correlation r = 0.316, p = 0.020).

11.6.2 Analysis of results by tidal cycle

Spring/neap tidal cycle

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

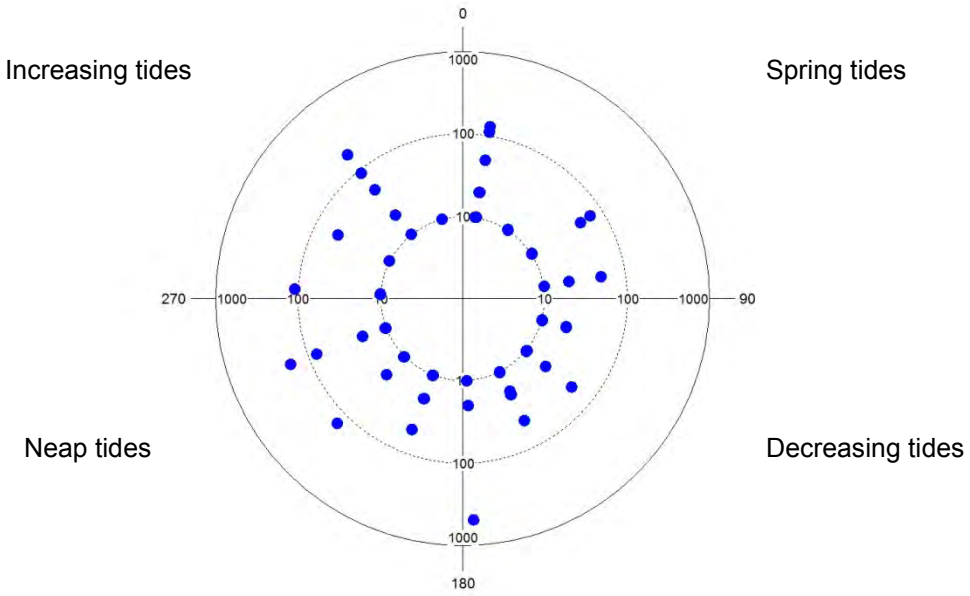


Figure 11.12 Polar plot of Inverlussa E. coli results on the spring/neap tidal cycle

A significant correlation was found between $\log_{10}$ *E. coli* results from Inverlussa and the spring/neap tidal cycle (circular-linear correlation r =0.237, p =0.023). None of the highest results occurred during spring tides.

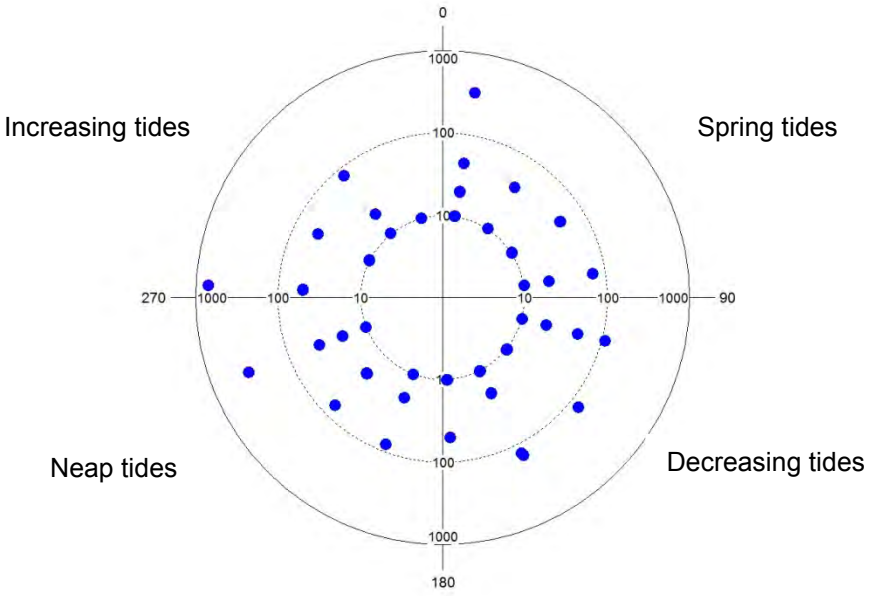


Figure 11.13 Polar plot of Rubha na Faing E. coli results on the spring/neap tidal cycle

No statistically significant correlation was found between $\log_{10}$ *E. coli* results from Rubha na Faing and the spring/neap tidal cycle (circular-linear correlation r = 0.188, p = 0.097).

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. Polar plots of *E. coli* results against the high/low tidal cycle for Inverlussa and Rubha na Faing are shown in Figures 11.14 and 11.15 respectively. High water is located at 0^{o} on the polar plot and low water at 180^{o}.

High and low water data for Craignure was extracted from POLTIPS-3 in November 2014. This site was the closest to the production area (approximately 7 km to the north) and it is assumed that the tidal state will be similar between sites.

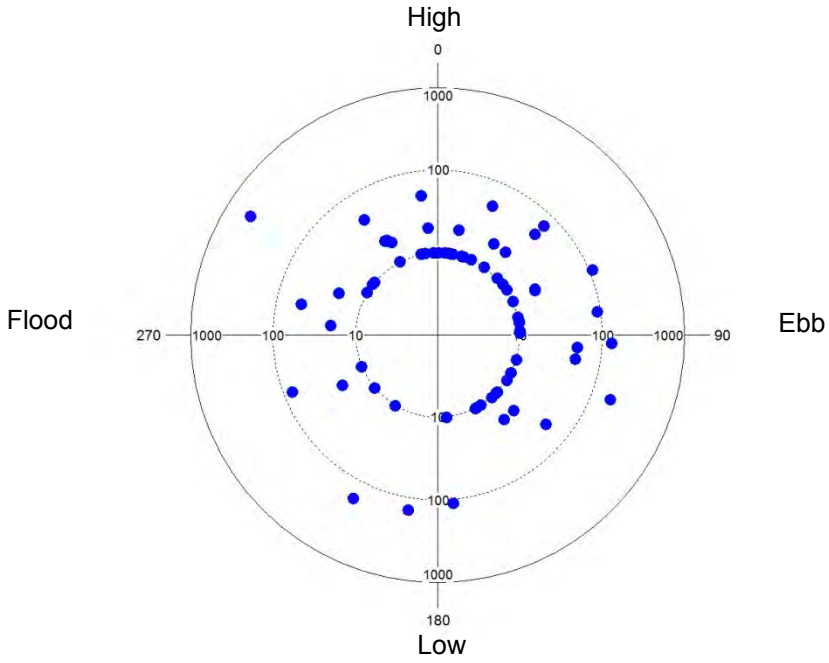


Figure 11.14 Polar plot of Inverlussa E. coli results on the high/low tidal cycle

No statistically significant correlation was found between $\log_{10}$ *E. coli* results from Inverlussa and the high/low tidal cycle (circular-linear correlation r = 0.158, p = 0.19).

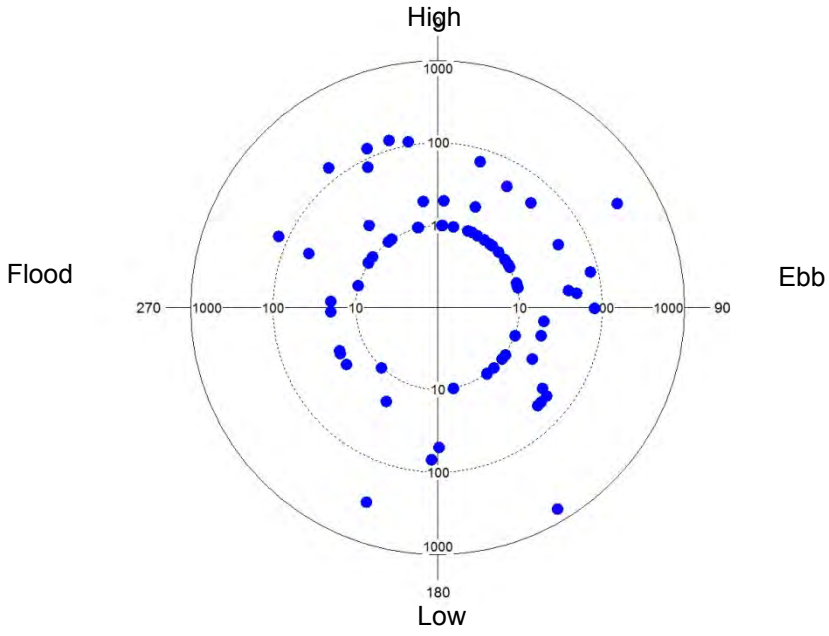


Figure 11.15 Polar plot of Rubha na Faing E. coli results on the high/low tidal cycle

No statistically significant correlation was found between $\log_{10}$ *E. coli* results from Rubha na Faing and the high/low tidal cycle (circular-linear correlation r = 0.14, p = 0.273).

11.6.3 Analysis of results by water temperature

Water temperature can affect survival time of bacteria in seawater (Burkhardt, *et al*., 2000). It can also affect the feeding and elimination rates in shellfish and therefore

may be an important predictor of *E. coli* levels in shellfish flesh. Water temperature is obviously closely related to season. Any correlation between temperatures and *E. coli* levels in shellfish flesh may therefore not be directly attributable to temperature, but to the other factors e.g. seasonal differences in livestock grazing patterns. Water temperature was recorded for 69 of the 70 Inverlussa sampling occasions and 68 of the 69 of the Rubha na Faing sampling occasions. Scatterplots of *E. coli* results against water temperature for Inverlussa and Rubha na Faing are shown in Figures 11.16 and 11.17 respectively. Jittering of results was applied at 0.02 (x-axis) and 0.001 (y-axis) respectively.

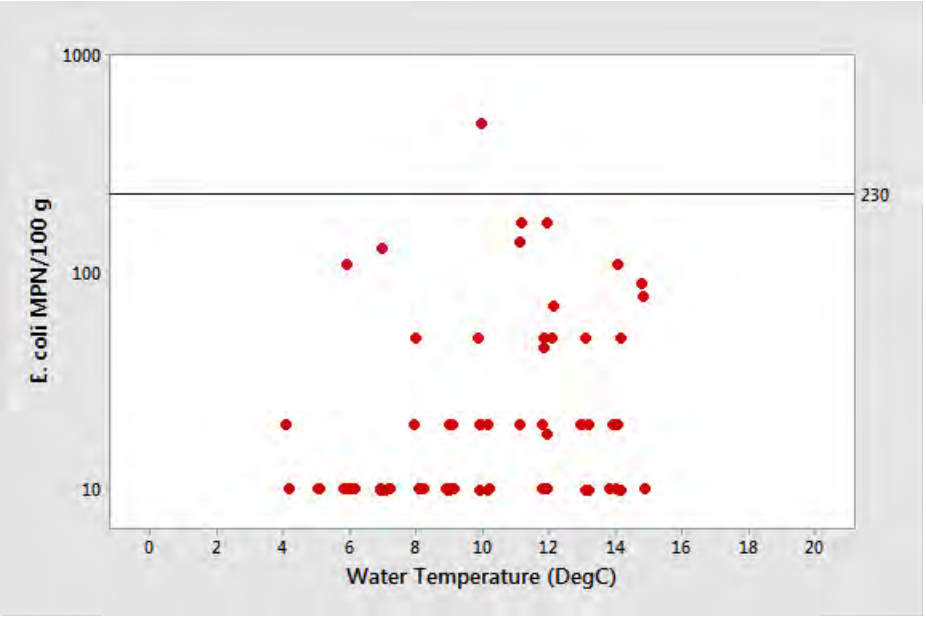


Figure 11.16 Scatterplot of E. coli results against water temperature at Inverlussa

A highly significant correlation was found between Inverlussa *E. coli* results and water temperature (Spearman's rank correlation r = 0.368, p = 0.002).

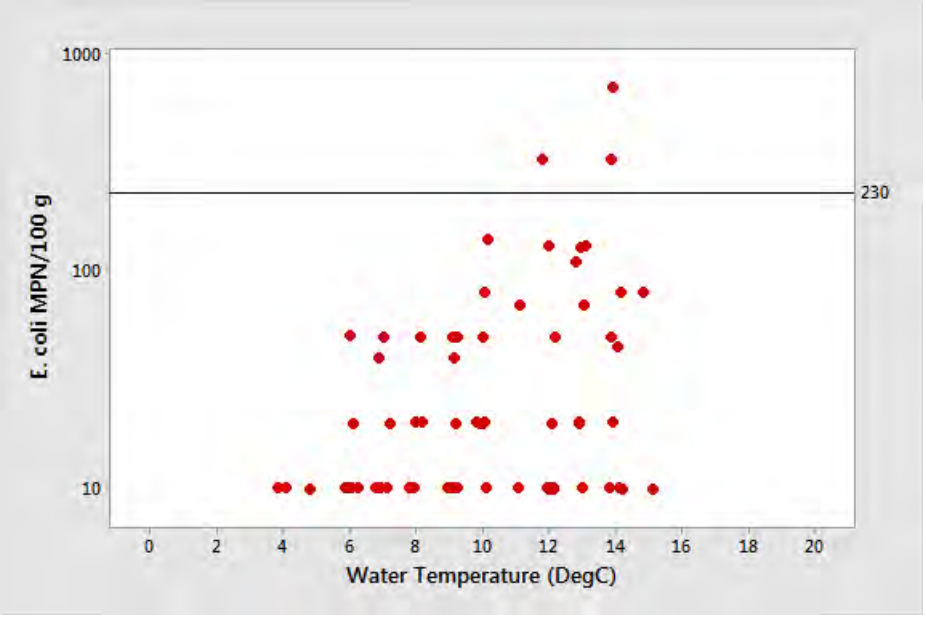


Figure 11.17 Scatterplot of E. coli results against water temperature at Rubha na Faing

A highly significant correlation was found between Rubha na Faing *E. coli* results and water temperature (Spearman's rank correlation r = 0.370, p = 0.002). The highest results occurred at water temperatures near the high end of the recorded range.

11.6.4 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence and hence freshwater borne contamination at a site. Scatterplots of *E. coli* results against salinity for Inverlussa and Rubha na Faing are shown in Figures 11.18 and 11.19 respectively. Salinity was recorded for 37 out of the 70 Inverlussa samples and 37 out of the 69 Rubha na Faing samples. Jittering was applied at 0.02 (x-axis) and 0.001 (y-axis) respectively.

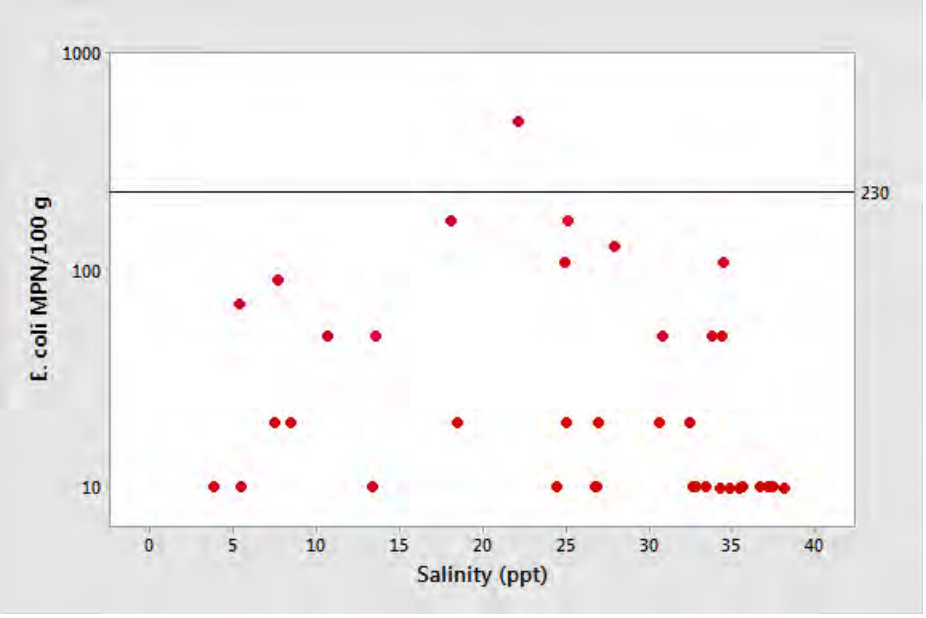


Figure 11.18 Scatterplot of E. coli results against salinity at Inverlussa

A significant negative correlation was found between Inverlussa *E. coli* results and salinity (Spearman's rank correlation r = -0.358, p = 0.030). A larger proportion of results greater than 20 *E. coli* MPN/100 g was associated with samples taken at salinities greater than 30 ppt than at salinities below this value.

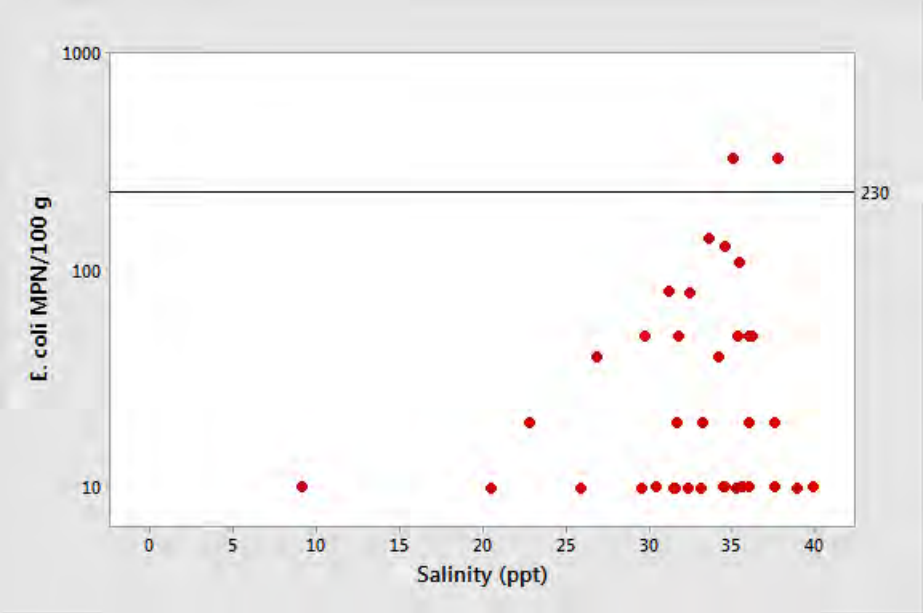


Figure 11.19 Scatterplot of E. coli results against salinity at Rubha na Faing

No statistically significant correlation was found between Rubha na Faing *E. coli* results and salinity (Spearman's rank correlation r = 0.097, p = 0.569).

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

One of the Inverlussa samples and three of the Rubha na Faing samples had results >230 *E. coli* MPN/100 g. These four samples are listed below in Table 11.2.

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

Site	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)
Inverlussa	10/05/2011	490	NM 7027 3019	3.8	43.7	10	22	Decreasing	Flood
Rubha na Faing	07/07/2009	330	NM 7036 2831	4.6	39.5	14	35	Spring	High
	06/07/2010	330	NM 7039 2834	10.9	58.5	12	38	Neap	Low
	11/09/2012	700	NM 7040 2833	15.1	31.3	14	-	Increasing	Ebb

-No data available

The elevated sample result from Inverlussa was taken in May 2011, from the current RMP. Rainfall over the previous two days was very low, while rainfall in the previous seven days was moderate. The three elevated sample results from Rubha na Faing were taken in July and September. They were taken approximately 39 m west, 12 m northeast and 8 m northeast of the RMP respectively. Previous two and seven day rainfall varied from low to moderate.

11.8 Summary and conclusions

No significant difference was found in mean log_{10}-transformed *E. coli* between the two sites. However, the highest result was seen at

Inverlussa

Regular sampling has taken place at Inverlussa since 2009. The current mussel farm boundaries as reported during the shoreline survey lies north of the current RMP and where sampling has been taking place. The majority of samples have been reported as having been taken at the RMP. The majority of sampling results have been low, with a large number sampling results of <20 *E. coli* MPN/100 g.

Although no statistically significant difference was found in results between seasons, an increase in results was noted in the trend line between July and October.

Results were significantly correlated with rainfall during the seven days prior to sampling. Significant positive correlations were also found with water temperature and salinity. Results were significantly correlated with the spring/neap tidal state.

Rubha na Faing

Sampling has taken place at the northern extent of the Killean site. The majority of samples were reported as having been taken at the RMP. A statistically significant difference was found between results and season, with results higher in autumn than in spring. An increase in the trend line was apparent between March and September.

Statistically significant correlations were found between results and antecedent rainfall over two and seven days prior to sampling. In both cases, this appears to be due to clustering of results below the limit of detection at low rainfall values.

A statistically significant correlation was found between results and water temperature, but not between results and salinity.

Results were not significantly correlated with tidal state.

12. Designated Waters Data

Shellfish Water Protected Areas

The Shellfish Waters Directive (2006/113/EC) was repealed on 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 Spelve Shellfish Water Protected Area (SWPA) extends beyond the previous Loch Spelve Shellfish Growing Water (SGW) to include the mouth of the loch(see 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.

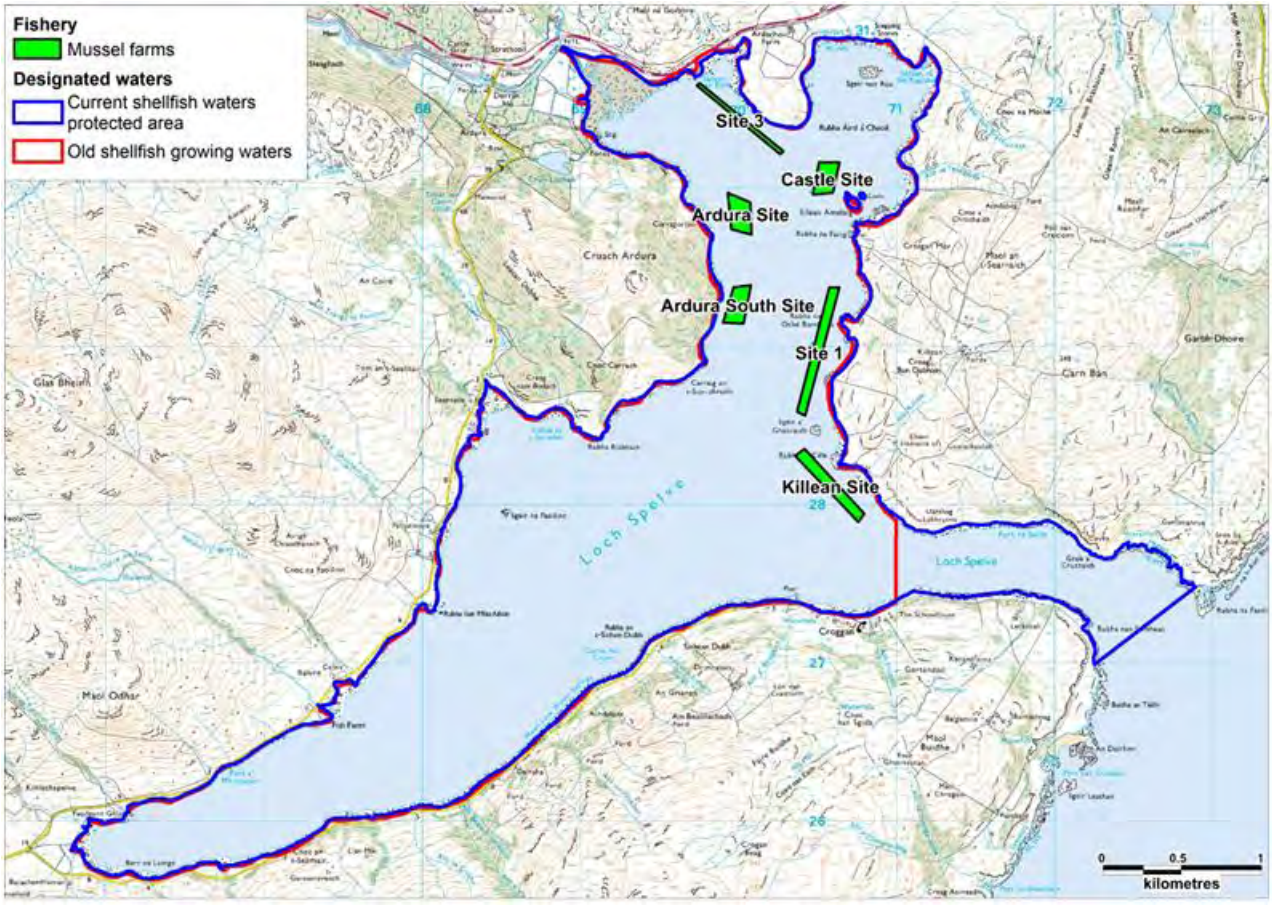


Figure 12.1 Designated shellfish water protected area – Loch Spelve

Bathing Waters

There are no designated bathing waters within Loch Spelve.

13. Bathymetry and Hydrodynamics

13.1 Introduction

13.1.1 The Study Area

Loch Spelve is situated on the south coast of the island of Mull on the west coast of Scotland. The landscape around the loch is characterised by hills with larger mountains found to the north and northwest of the assessment area. The assessment area boundary at the entrance of the loch is narrow and lies between Rubha na Faoilinn to the north and Rubha nan Saithean to the south.

Loch Spelve is comprised of two arms extending from a single, narrow entrance to the loch from the adjacent Firth of Lorn. Within the loch, the northern arm extends north towards the A849 road, while the southern arm extends in a southwesterly direction and gradually narrows in width towards Kinlochspelve.

Numerous small streams and burns flow into Loch Spelve, as well as the Lussa River, which flows into the northern arm of Loch Spelve at Strathcoil.

The total length of Loch Spelve along its northeast to southwest axis is 7.7 km (Edwards & Sharples, 1986). The width of the loch along this axis averages 0.5 – 1.0 km, but is closer to 1.5 km at its widest point where the entrance channel joins the main body of the loch. The entrance channel is oriented in an east-west direction and is approximately 3 km in length and 0.5 km in width.

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Figure 13.1 Extent of the Loch Spelve hydrographic study area

Coordinates for Loch Spelve:

56.3878° N, 005.7314° W
OS NM 696280

13.2 Bathymetry and Hydrodynamics

13.2.1 Bathymetry

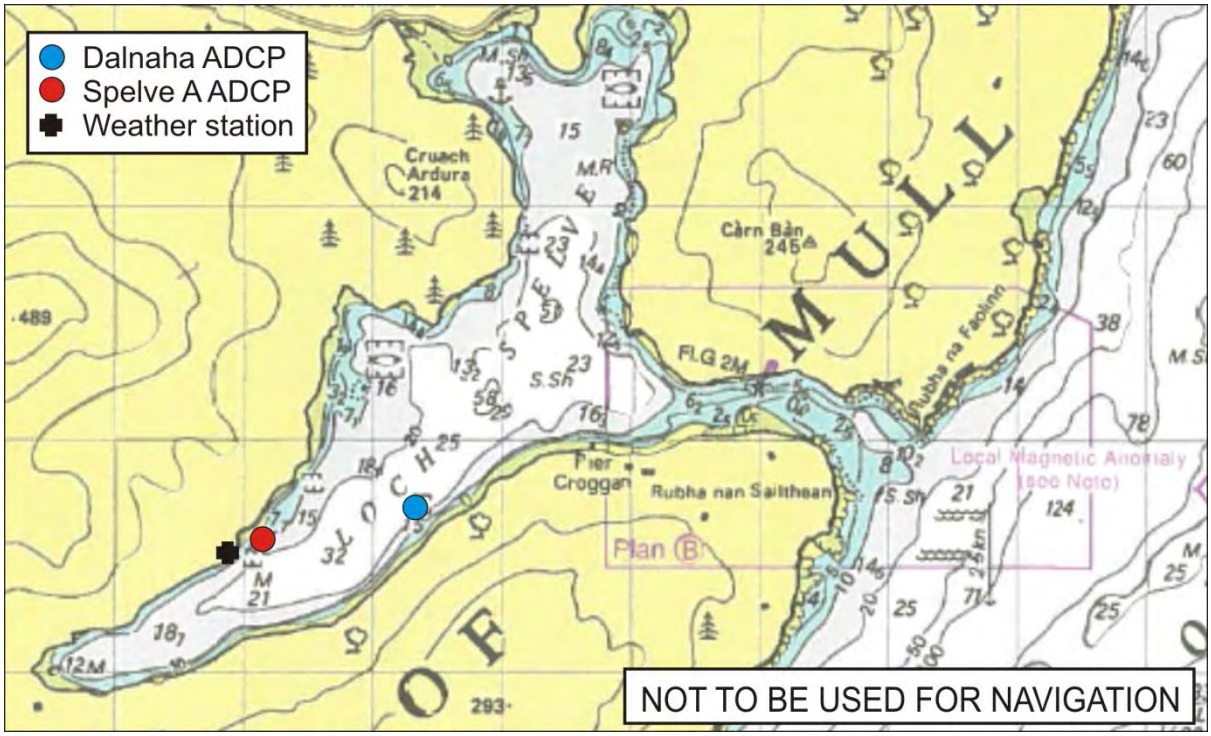


Figure 13.2 Admiralty chart (2387) extract for Loch Spelve. Locations of ADCPs and weather stations within assessment area are shown.

Figure 13.2 shows the bathymetry of Loch Spelve.

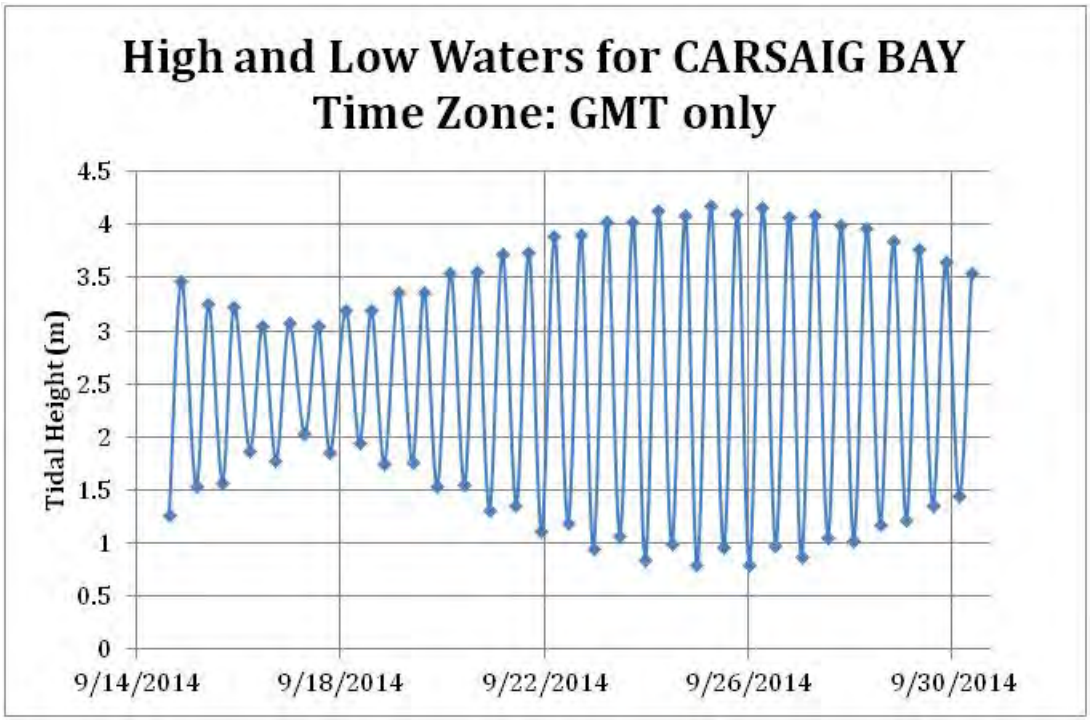
Loch Spelve has a single sill, extending across the central portion of the loch's entrance channel. The sill is 400 m in width and has a mean depth of 3 m and a maximum depth of 5 m along its northern edge (Edwards & Sharples, 1986). To the east of the sill, water depths gradually increase towards the assessment area boundary, then drop off steeply into a deep portion of the Firth of Lorn. To the west of the sill, depths also increase towards the central portion of Loch Spelve, and reach a maximum depth of 58 m.

The mean depth of the assessment area at low water is 17.2 m, while the estimated low water volume is 1.52 x 10^8 m^3 (Edwards & Sharples, 1986).

13.2.2 Tides

Data on tidal information is provided based on tidal characteristics determined from Carsaig Bay, approximately 10 km to the southwest of Loch Spelve.

Standard tidal data for Carsaig Bay, centred around the survey date of 22nd September 2014, are shown in Figure 13.3. Tidal predictions for Carsaig Bay indicate that in this region the tidal characteristics are semi-diurnal, with a well-developed spring-neap cycle. The tidal characteristics at the entrance to Loch Spelve will be similar to Carsaig Bay but the precise nature of the tide within Loch Spelve (times and heights) will be modified due to the extensive shallow sill at the entrance.



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

Figure 13.3 Two week tidal curve for Carsaig Bay.

Tidal heights at Carsaig Bay, data from Poltips3 [www.pol.ac.uk/appl/poltips3]:

Mean High Water Springs = 4.1 m
Mean Low Water Springs = 0.6 m
Mean High Water Neaps = 3.1 m
Mean Low Water Neaps = 1.8 m

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

Springs: 3.08×10^7 m^3
Neaps: 1.14×10^7 m^3

13.2.3 Tidal Streams and Currents

There are no published tidal diamonds for this area. However, admiralty chart extracts suggest substantial current flows through the mouth of Loch Spelve, though no flood or ebb current speeds are provided. Anecdotally they are reported to be around 1.5- 2.0 m/s. Enhancement of the speed of tidal streams occurs in the entrance to Loch Spelve due to the shallow nature of the sill. A tidal race or tidal rapids can be found immediately outside the assessment area in the Firth of Lorn, and is associated with current speeds of up to 1.5 m/s.

Current meter data were available at two specified sites within the assessment area: Spelve A and Dalnaha. Data were obtained from SEPA for the two sites, whose locations are shown in Figure 13.4.

Each survey spanned a period of at least fifteen days, focussing on a half-lunar period in order to capture a spring-neap cycle: 8th-27th October 1999 at Spelve A (Dalriada Solutions Ltd., 1999) and 17th October to 6th November 2007 at Dalnaha (TransTech Ltd. , 2009).

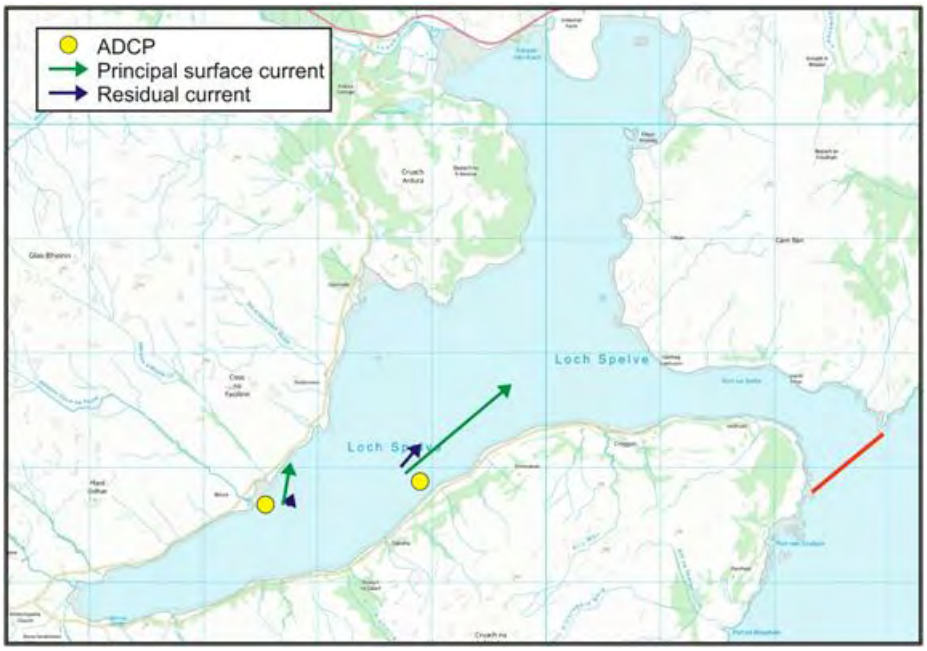


Figure 13.4 Map showing Loch Spelve ADCP sample sites within the assessment area. Using the surface principal current amplitude and residual current velocities and the assumption of a uniform sinusoidal tide, the cumulative transport distance and direction that might be expected during each phase of the tide is shown above.

Data from Spelve A, 56°22.457' N, 05°45.943' W, were collected between 08/10/99 and 27/10/99 and are summarised in Table 13.1. The average water depth recorded for the duration of the survey was 19 m.

Mean current speeds suggest that there is a slight gradient in flow between the sub-surface and the sea bed, with speed decreasing with increasing depth. The strongest currents at the sea surface are most frequently characterised by flows along a southwesterly to northeasterly axis, aligned with the adjacent shoreline. The main

axis of flow of currents at mid-water and near-bed depths was less distinct, as flow rates were not as strong and were recorded from all directions. Residual current speeds were slightly higher at mid-water depths, and generally had a strong north-south directional component. The greatest current speeds were recorded during the day or two after both spring and neap tides, while current speeds were generally greater during the spring tide period than during neap tides.

Table 13.1 Spelve A current data measured in 1999

Average Depth	Near-bed (2 m above seabed)	Mid-water (vector averaged surface & bottom meter data)	Sub-surface (16 m from seabed)
Mean Speed (ms^{-1})	0.012	0.016	0.019
Maximum Speed (ms^{-1})	0.116	0.132	0.200
Principal Axis Amp & Dir (ms^{-1}) & (^oM)	0.018 (280)	0.019 (170)	0.027 (10)
Residual speed (ms^{-1})	0.005	0.008	0.004
Residual direction (^oM)	322.2	3.8	27.3

A weather station was also deployed during the Spelve A survey. Wind speeds were on average 3.9 ms^{-1}, and reached a maximum of 12.3 ms^{-1}. Winds most frequently came from a southeasterly or southerly direction, but were also recorded from northeasterly and northwesterly directions.

Data were collected from Dalnaha, 56.377798° N -005.745755° W, between 17/10/2007 and 06/11/2007 and are summarised in Table 13.2. The average water depth recorded during the survey was 29.3 m.

Calculated mean current speeds suggest that flows are greater at this site than at Spelve A, and strongest near the sea surface. Currents flowed most frequently along a northeast-southwest axis, aligned with the adjacent shoreline. While stronger currents speeds at all depths were associated with the period of spring tides, at the sea surface the strongest currents occurred outside the spring tide period, and may have been related to a period of strong southwesterly winds between 31/10/07 and 01/11/07. Residual currents were strongest at the seabed, where they were aligned in a northerly direction.

A weather station was also deployed during the Dalnaha survey at the same location as in the Spelve A survey. Winds during the deployment averaged 4.35 ms^{-1}, or a ‘light breeze’. The maximum recorded wind speed was 12.37 ms^{-1}. Winds most frequently came from the southwest, and occasionally from the south during this survey.

Table 13.2 Dalnaha current data measured in 2007

Average Depth	Near-bed (2.0 m above seabed)	Mid-water (15.6 m above seabed)	Sub-surface (25.6 m from seabed)
Mean Speed (ms^{-1})	0.050	0.040	0.054
Maximum Speed (ms^{-1})	0.198	0.178	0.257
Principal Axis Amp & Dir (ms^{-1}) & (^oM)	0.066 (55)	0.066 (45)	0.088 (50)
Residual speed (ms^{-1})	0.033	0.000	0.019
Residual direction (^oM)	9.7	94.9	40.5

In general the current meter data from Spelve A and Dalnaha suggest that Loch Spelve is moderately quiescent.

Using the largest recorded mean surface principal current and assuming a uniform sinusoidal tide, the cumulative transport that might be expected during each phase of the tide (approximately 6 hours) has been estimated for the Spelve A site as 0.4 km (based on a surface principal current amplitude of 0.027 ms^{-1}) and for the Dalnaha site as 1.2 km (based on a surface principal current amplitude of 0.088 ms^{-1}). No distinction is made here for springs and neaps.

Dispersion is an important property of a water body with respect to redistribution of contaminants over time. A study of the environmental impacts of mussel farming in Scotland (Wilding, et al., 2011) modelled the flux of biodeposits from mussel longlines in Loch Spelve, and suggested that the reasonable depth and currents found in the loch increased dispersion such that settling material was dispersed widely. Dispersion is likely to be particularly enhanced in the vicinity of the entrance to the loch where tidal current speeds are increased by the narrow loch entrance and the shallow sill.

Dispersion of surface contaminants could be enhanced by wave energy within Loch Spelve, though the narrow connection between the loch and the wider Firth of Lorn means that swell originating outside the loch is unlikely to be the major source of wave energy. Rather, short period waves generated within the loch are more likely to enhance dispersion of contaminants.

13.2.4 River/Freshwater Inflow

One river, the Lussa River, flows into Loch Spelve's northern arm at Strathcoil. Numerous other small streams and burns flow into Loch Spelve, including Abhainn Bhearnach, and Abhainn a' Choire, which flow into the northern arm of the loch, and Abhainn a'Bhail Uir, Abhainn Coire na Feola, Allt na Faoilinn Glaise, and Allt na Teangaidh Baine, which flow into the southern arm of the Loch.

The annual precipitation in the area is approximately 2250 mm and the annual freshwater runoff is estimated as 152.0 M m^3 yr^{-1} (Edwards & Sharples, 1986). The ratio of freshwater flow to tidal flow in Loch Spelve is lower than in many sea lochs at

approximately 1:105 (Edwards & Sharples, 1986), and this ratio will be seasonally variable.

13.2.5 Meteorology

The nearest weather station for which a continuous rainfall dataset is available is located at Lismore; Frackersaig Farm. This station is situated approximately 20 km to the northeast of the assessment area. Rainfall records are available from January 2008 to December 2013.

While 2010 generally had the lowest daily rainfall, the highest rainfall for this time period was recorded in 2011 (2354 mm). High rainfall values (> 40 mm d^{-1}) occurred in every year except 2010, but rainfall events of > 50 mm d^{-1} were recorded in 2008, 2009 and 2011. Rainfall events of > 30 mm d^{-1} occurred in all months except February and April, and high rainfall values of 50 mm/d were seen in January, and September. Daily rainfall varied seasonally, from lower values in early summer months (April - June) to higher values in autumn and winter months (November – February). Mean rainfall at Lismore: Frackersaig Farm peaks in November. For the duration of the dataset, daily rainfall of below 1 mm occurred on 47% of days, while daily rainfall above 10 mm occurred on 17% of days.

Run-off due to rainfall is expected to be highest in the autumn and winter months. However, it must also be noted that high rainfall events occurred in most months and consequently that high run-off can occur throughout the year.

Wind data were obtained from Tiree, located 72 km to the west of the assessment area. Given the distance between these two locations and varying topography, wind statistics may not be directly transferrable to the specific production area in Loch Spelve. 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 from the south and southwest. Seasonally the strongest winds occurred during the winter and came from this quarter. Typically the wind came from the south and west throughout the year but the summer and autumn also saw winds from the north. Nevertheless, the strength and direction of wind in Loch Spelve are known locally to be influenced strongly by the surrounding topography.

13.2.6 Model Assessment

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

represent an ‘average’ year. The model has been tuned and validated for Lochs Creran and Etive. A full validation for Loch Spelve has not been done.

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

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

Parameter	Value
Tidal Volume Flux ($m^3 s^{-1}$)	513
Estuarine Circulation Volume Flux ($m^3 s^{-1}$)	25
Median Flushing Time (days)	0.9
95%-ile Flushing Time (days)	1.5

The ratio of tidal volume flux to estuarine circulation volume flux is 20. Values greater than 2 are considered to represent locations where tidal exchange is the dominating exchange process (Gillibrand, et al., 2013).

The exchange time for the surface and intermediate layers is calculated as approximately 1 day which is slightly less compared to the tidal prism estimate of 3.5 days (Marine Scotland, 2012) and 3 days (Edwards & Sharples, 1986). Nevertheless, the short flushing time is indicative of an effectively flushed system.

13.3 Hydrographic Assessment

13.3.1 Surface Flow

The assessment area does have a point source of freshwater towards the head of the northern arm of the loch but also has numerous smaller rivers discharging around the perimeter. The meteorological data indicate a moderate seasonal variation in freshwater discharge which will create seasonal variation in the degree to which the site is stratified by freshwater.

However, it appears from the tidal/fresh water ratios of volume and exchange rate that the freshwater contribution to the exchange characteristics of the site is rather small. Consequently the overall exchange properties of the assessment area will have a minimal seasonal variation, rather being dominated by the tidal influence. The role of freshwater in this system is the potential formation of a distinct fresh surface layer makes it susceptible also to the influence of wind giving rise to current flow that can vary with depth. This is noted in the data from Dalnaha and described in Section 13.2.3. However, it is likely that these layers will become rather quickly mixed during periods of strong wind and will certainly become mixed during transit through the loch entrance.

Loch Spelve is relatively simple in terms of the topography of the loch. From the current meter records it is clear that the flow of water is influenced strongly by the local bathymetry and it is expected that the dominant flow within the assessment area will follow the axis of the loch towards the sill on ebb tides and away from the sill on flood tides. The cumulative transport distance on each phase (flood/ebb) of the tide has been estimated to vary from 0.4 km to 1.2 km suggesting that there may be enhancement of the flow closer to the loch entrance. This variation will also tend to enhance dispersion in the Loch.

The residual flows during the period of measurement are typically weak. Surface residual flows would be enhanced by winds blowing across the loch.

Net transport of contaminants is related to the residual flow. The net transport over a tidal cycle of approximately 12 hours would be around 0.8 km or less. It is likely that any surface contaminant in the assessment area would generally be transported seaward under the influence of any estuarine circulation.

13.3.2 Exchange Properties

Exchange modelling predicts a mean flushing time for Loch Spelve of around 1 day which implies a well flushed system. It is worth noting that the simple tidal prism method which is used in some box modelling applications e.g. the Sea Loch Catalogue (Edwards & Sharples, 1986) also gives a short flushing time.

Current flow has been measured at two locations within the assessment area yet each current meter was only deployed for a relatively short period of the year, limiting detailed seasonal analysis. Nevertheless, the tidal flows are generally moderate although values vary between sites and residual flows are also moderate. There is rather little descriptive literature on exchange properties for the area. The box model provides consistent information on the exchange properties of the site. Consequently, the confidence level of this assessment is MEDIUM.

14. Shoreline Survey Overview

The Loch Spelve shoreline survey was conducted on the 22nd and 23rd September 2014. No rainfall was recorded in the 48 hours prior to the survey. Light rain fell during both survey days.

The fishery consisted of six long-line mussel farms. These were identified by Mr Wilson (the director of Inverlussa Marine Services) as Site 3 (three lines), Castle Site (five lines), Killean Site (six lines), Site 1 (four lines), Ardura (seven lines), and South Ardura (six lines). Mr Wilson also stated they had converted the farm system from pegged lines to a continuous loop system. Harvesting usually takes place March to December.

The surrounding shoreline was sparsely populated. No public facilities, amenities, holiday houses or caravan parks/campsites were noted. One dwelling house and a farm house were noted at the north end of the loch, with a second farm house noted on the northwest shore. Houses along the southern shoreline were noted during boat work. No obvious sewage discharges were observed. Two boats were harvesting the Inverlussa site. Cattle and sheep were observed around the north end of the loch, mainly associated with the farms located there. Cattle droppings were also seen on the northeast shore of the loch.

The surrounding land was predominantly rough pasture land used for grazing. Areas of deciduous forest were also noted.

Nine watercourses were measured and sampled. Freshwater sample results ranged from <10 to 430 *E. coli* cfu/100 ml. Four other watercourses were observed along the north and northeast shorelines, but were not sampled or measured.

Gulls were numerous, with 100-200 observed around Castle Site. Greylag geese and their droppings were noted on the northern shoreline, Four mute swans were observed feeding on mussels at the Ardura South site. Four adult common seals and one pup were seen on the eastern shoreline.

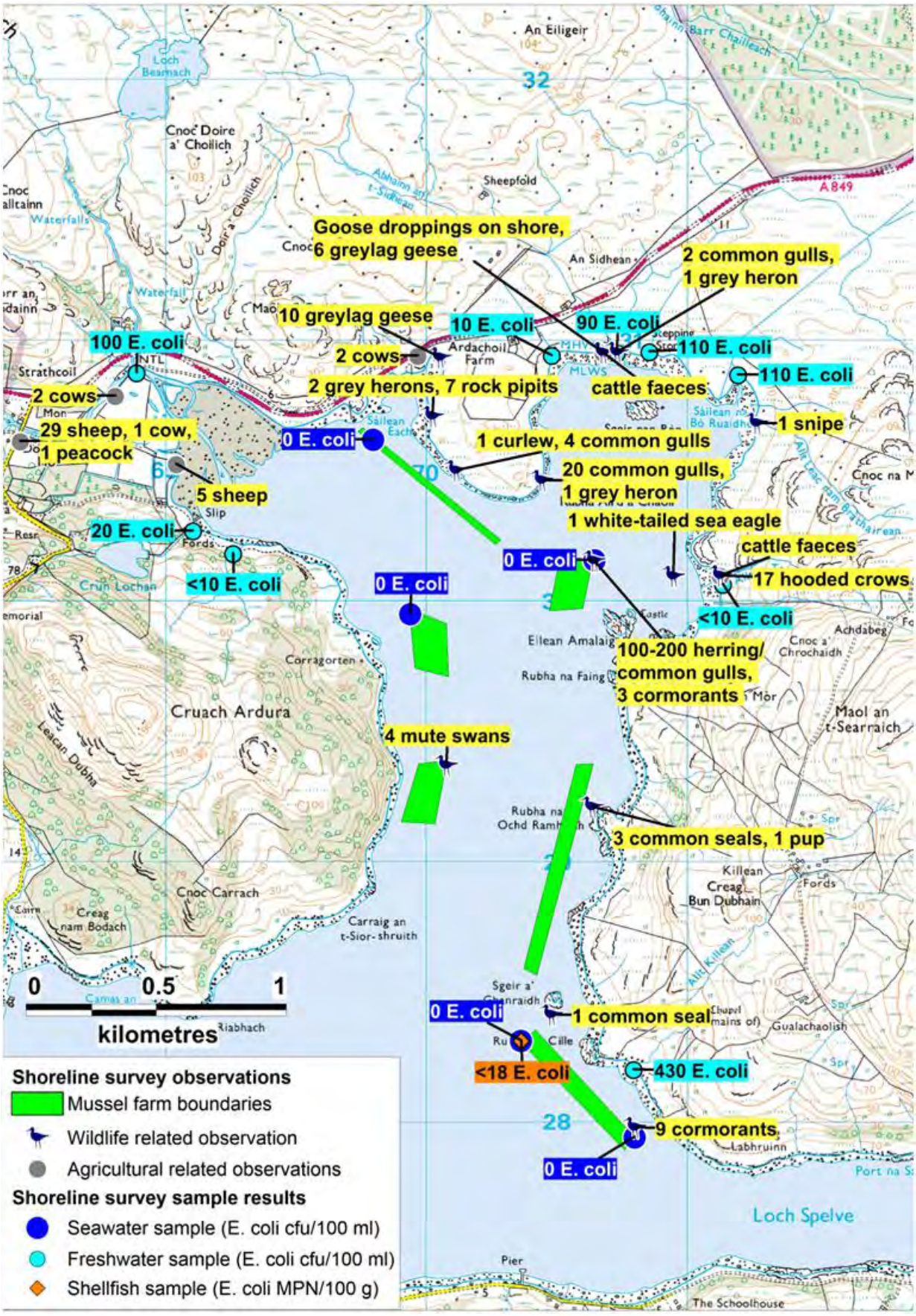


Figure 14.1 Map of shoreline survey observations at Loch Spelve

15. Bacteriological Survey

A bacteriological survey was undertaken at Loch Spelve to help inform the assessment of spatial impacts from potential sources of contamination in the area. Sampling was undertaken on two occasions at three locations that had been sampled during the shoreline survey. Water samples were taken from near the surface at the locations shown in the map in Figure 15.1. The results, together with the maximum values for these at each site, are given in Table 15.1. Due to the large proportion of negative results, it was not considered appropriate to determine geometric mean values at each point.

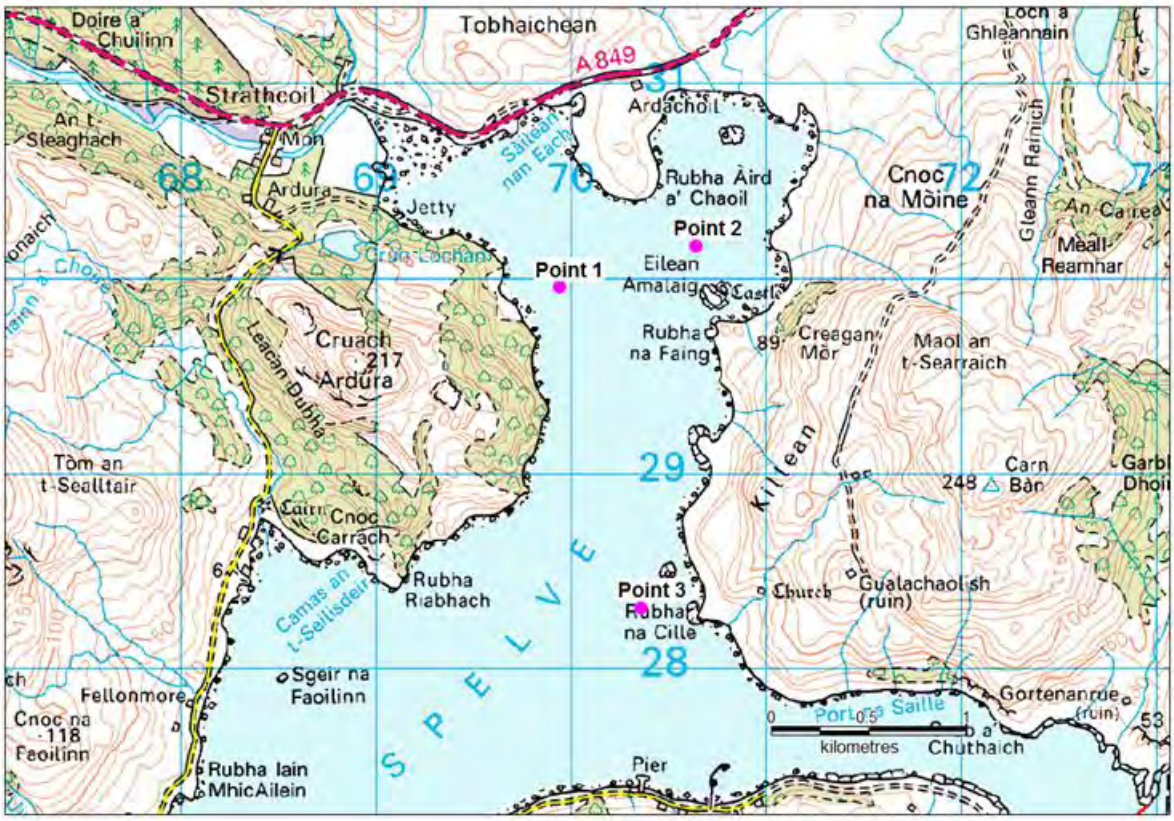


Figure 15.1 Bacteriological survey sampling locations

Table 15.1. Bacteriological survey results

Sample point	Site name	NGR	*E. coli* cfu/100 ml				
			22/09/2014	18/11/2014	2/12/2014	Geometric mean	Maximum
1	Point 1	NM 6994 2996	0	3	1	**	3
2	Point 2	NM 7064 3015	0	0	0	**	0
3	Point 3	NM 7037 2831	0	0	2	**	2

** not calculated

All results were very low. They were above zero twice at Point 1, and this location yielded the highest result.

16. Overall Assessment

Human sewage impacts

Consented point source discharges of human sewage to the northern arm of the loch are confined to private septic tanks that go to freshwater or soakaway. They are located at Ardura, Seanvaile and Croggan. Any impacts are likely to be greatest at the fisheries located at the northwestern end of the loch although the discharges located at Croggan may affect the Killain site if currents flow north across the inner loch entrance under certain environmental conditions.

Agricultural impacts

Diffuse contamination from livestock grazed around the loch is most likely where the animals have access to the shoreline and any watercourses discharging to the loch. Sheep and evidence of cattle were noted on and near the shoreline during the shoreline survey at Croggan Pier in 2011. Most of the livestock seen in 2014 were around the north shore of the loch, where two farms and areas of improved pasture were noted. The largest pasture area is around the mouth of the River Lussa, on the northwest side of the loch. Any contamination arising from this area would be carried in freshwater runoff to the fishery, and impacts would be most likely at Site 3 and the Ardura Site.

Wildlife impacts

Seabirds are expected to constitute the main type of wildlife that will contribute to faecal loadings at the shellfish farms. Any impact are likely to be greatest towards the northeastern end of the loch. Seals and cetaceans may also contribute sporadically to background levels in the loch.

Seasonal variation

No evidence was found for any significant seasonal variation in human population bordering the production area. A small number of holiday homes were found at Croggan during the 2011 shoreline survey there. Seasonal variation in livestock number is expected, with higher numbers likely to be present in spring and summer. There is also seasonal variation in rainfall, with higher rainfall seen from August to November.

Significant seasonal variation in results was seen at Rubha na Faing, with results higher in autumn than in spring. However, a similar seasonal trend toward higher results between July and October was apparent at both production areas.

Watercourses

The largest watercourse discharging to the upper loch is the River Lussa, which at the time of shoreline survey carried an estimated loading of 5.2x 10^{10} *E. coli* cfu/day. Overall, freshwater inputs would be expected to provide higher levels of contamination to the mussel farms at the northern end of the loch (Site 3, Ardura Site and Castle Site) and to the Killean Site with the highest impact expected from the watercourses that discharge directly adjacent to the shellfish farms.

Ardura Site is situated nearest the outflow from the River Lussa, and the bacteriological survey showed more results above the limit of detection at Ardura Site than at Killean Site.

A significant correlation was found between Inverlussa results and 7-day rainfall, whereas at Rubha na Faing results correlated with both 2-day and 7-day rainfall. However, no correlation was seen between results and reported salinity at Rubha na Faing although this was seen at Inverlussa. Both sites are therefore affected by rainfall runoff.

Movement of contaminants

It is expected that the dominant flow within the assessment area will follow the axis of the loch towards the sill on ebb tides and away from the sill on flood tides. The cumulative transport distance on each phase (flood/ebb) of the tide has been estimated to vary from 0.4 km to 1.2 km suggesting that there may be enhancement of the flow closer to the loch entrance. No evidence was available to determine whether flows can occur across the inner loch entrance: however, if this does occur it would most likely be under the influence of strong southerly winds.

No specific data was found on flows at the north end of the loch. Flows from the River Lussa may form a fresh water cap flowing southward at the surface and toward the mouth of the loch. Salinity profiles taken at five locations around the area during the shoreline survey showed no marked difference in salinity between locations or with depth. All recorded salinities were approximately 33.5 psu with the observed deviations being within the error of the instrument.

Temporal and geographical patterns of sampling results

Monitoring results at both production areas were low and stable over the period assessed (2007-2014). The highest result was obtained from the Rubha na Faing monitoring point although there was no significant difference in the average *E. coli* levels at the two sites.

Conclusions

The mussel farm at Castle Site straddles the two production areas and therefore the boundaries need to be amended to ensure that individual farms are not split. The

main sources of faecal contamination to both production areas are diffuse faecal contamination from livestock and wildlife sources. There is very little human population in the area, and the septic discharges from those nearest the mussel farms are consented to discharge to soakaway. Predicted transport of contaminants is low and therefore the most important sources in relation to the fishery are those closest to the mussel farms. The River Lussa is the most significant source at the head of the loch, and flow from this source may be carried southward at the surface for a greater distance than that predicted for contaminants in the main body of the loch. Results from Rubha na Faing showed a stronger seasonality than those from Inverlussa, however in both areas results have been largely below 230 *E. coli* MPN/100 g.

17. Recommendations

Production area

It is recommended that the production areas be combined with boundaries defined as the area bounded by lines drawn between NM 6922 2862 and NM 7100 2739, and between NM 7100 2739 and NM 7100 2793, extending to MHWS.

RMP

It is recommended that the RMP be moved to NM 6995 2995, at the north end of Ardura Site in order to reflect contamination arising from the River Lussa and potential sources at the northwest end of the loch.

Tolerance

A sampling tolerance of 40 m is recommended to allow for movement of the mussel lines.

Depth of sampling

Recommended sampling depth is 1-3 m to reflect contamination in surface waters.

Frequency

Monthly sampling frequency is recommended.

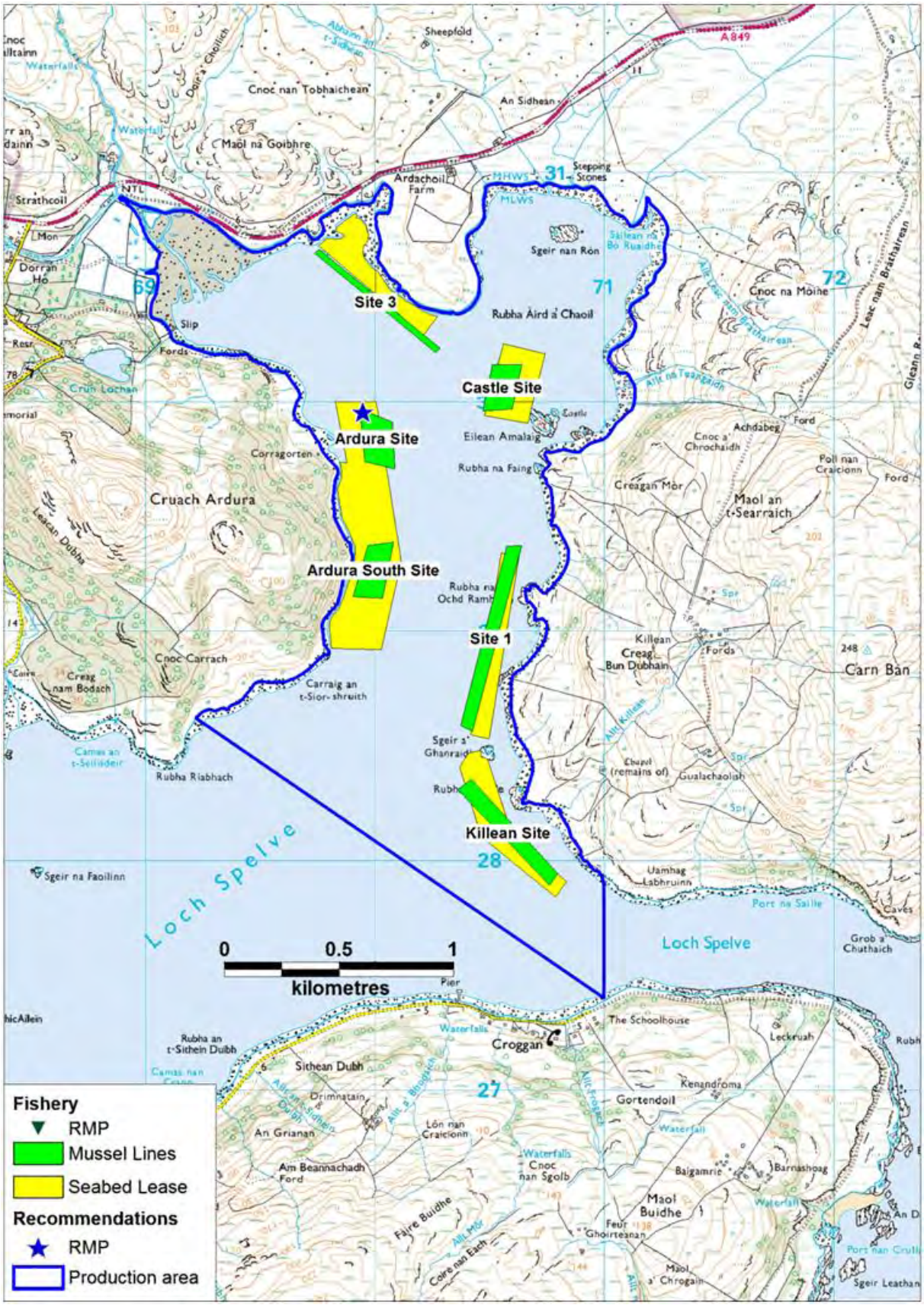


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Figure 17.1 Map of recommendations at Loch Spelve: Inverlussa And Rubha Na Faing

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2. **Tables of Typical Faecal Bacteria Concentrations**
3. **Statistical Data**
4. **Hydrographic Section Glossary**
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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.

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2. Tables of Typical Faecal Bacteria Concentrations

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

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

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

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

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

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

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

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

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

Source: (Gauthier & Bedard, 1986)

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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

Inverlussa One-way ANOVA: Logec versus Season

Method
Null hypothesis All means are equal
Alternative hypothesis At least one mean is different
Significance level α = 0.05
Equal variances were assumed for the analysis.
Factor Information
Factor Levels Values
Season 4 1, 2, 3, 4
Analysis of Variance
Source DF Adj SS Adj MS F-Value P-Value
Season 3 1.030 0.3434 2.11 0.108
Error 66 10.758 0.1630
Total 69 11.788
Model Summary
S R-sq R-sq(adj) R-sq(pred)
0.403729 8.74% 4.59% 0.00%
Means
Season N Mean StDev 95% CI
1 18 1.1662 0.4221 (0.9762, 1.3562)
2 18 1.451 0.444 (1.261, 1.641)
3 17 1.3901 0.3603 (1.1946, 1.5856)
4 17 1.2033 0.3785 (1.0078, 1.3988)
Pooled StDev = 0.403729

Tukey Pairwise Comparisons
Grouping Information Using the Tukey Method and 95% Confidence
Season N Mean Grouping
2 18 1.451 A
3 17 1.3901 A
4 17 1.2033 A
1 18 1.1662 A
Means that do not share a letter are significantly different.

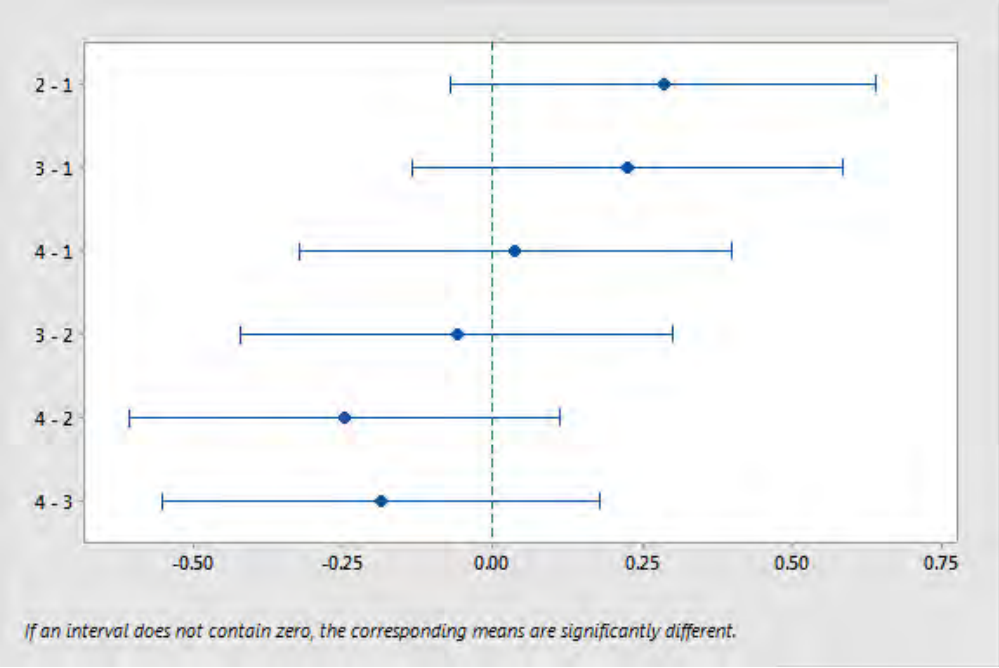

Figure 1 Inverlussa Tukey Pairwise Comparisons

Rubhan a Faing 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 2.481 0.8271 4.54 0.006
Error 65 11.841 0.1822
Total 68 14.322
Model Summary
S R-sq R-sq(adj) R-sq(pred)
0.426807 17.32% 13.51% 6.94%
Means
Season N Mean StDev 95% CI
1 18 1.1613 0.2593 (0.9604, 1.3622)
2 18 1.516 0.561 (1.315, 1.717)
3 17 1.610 0.504 (1.404, 1.817)
4 16 1.2251 0.2932 (1.0120, 1.4382)
Pooled StDev = 0.426807

Tukey Pairwise Comparisons
Grouping Information Using the Tukey Method and 95% Confidence
Season N Mean Grouping
3 17 1.610 A
2 18 1.516 A B
4 16 1.2251 A B
1 18 1.1613 B
Means that do not share a letter are significantly different.

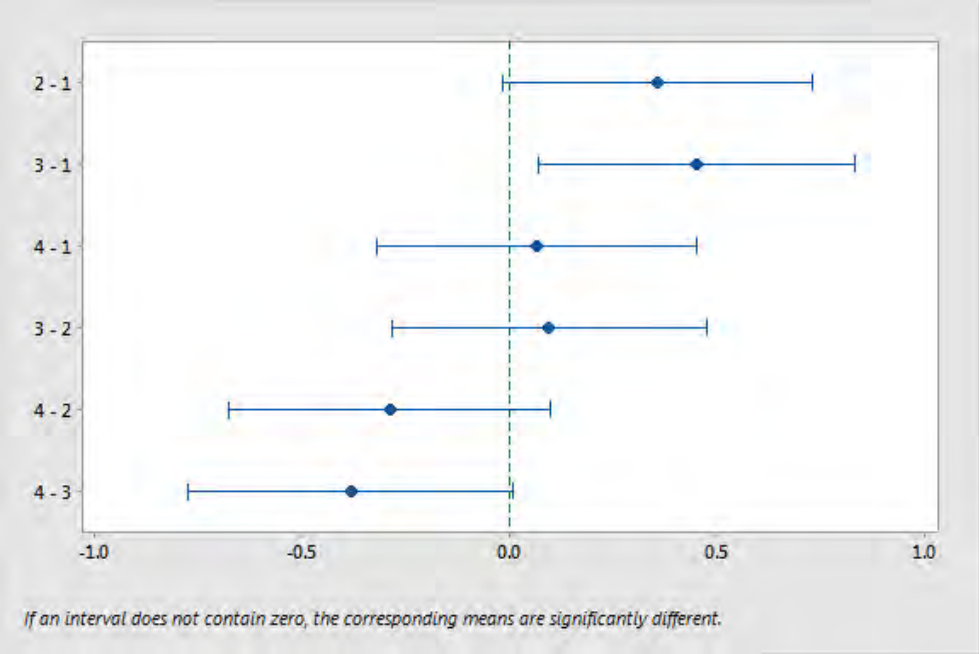

Figure 2 Rubha na Faing Tukey Pairwise Comparisons

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

Document Number	B0067_Shoreline 0041

Revision History

Revision	Changes	Date
A	Issue for internal review	29/09/2014
B	Second issue for internal review	07/10/2014
01	First formal issue to Cefas	09/10/2014
02	Second issue to Cefas incorporating corrections from Issue01	21/11/2014

	Name & Position	Date
Author	Eilidh Cole & Debra Brennan	29/09/2014
Checked	Andrea Veszelovszki	17/11/2014
Approved	Mark Hart	21/11/2014

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

Production area: Loch Spelve
Site name: Inverlussa
SIN: AB-200-056-08
Site name: Site 1
SIN: AB-200-057-08
Existing RMP: NM 7027 3018
Site name: Rubha na Faing
SIN: AB-202-059-08
Existing RMP: NM 7039 2833

NB: the site names listed above were found to be different and there were six sites in total when the survey team visited the production area. The names that were used by the mussel farm manager, Mr Douglas Wilson are listed in the Fishery paragraph below.

Species: Common Mussels
Harvester: Cameron MacLean
Local Authority: Highland Council: Highland Lochaber
Status: Existing area
Date Surveyed: 22/09/2014 – 23/09/2014
Surveyed by: Debra Brennan & Eilidh Cole

Area Surveyed

Approximately 1.5 km of the west shoreline of Loch Spelve at Ardura and 2.5 km of eastern shoreline near Killean were surveyed by boat. A further 1 km or so of the western shoreline was surveyed by the team by foot beginning from Dorran House heading southeast. Approximately 2.5 km of the northwestern shoreline was surveyed by foot from the area surrounding Ardachoil Farm heading west until the area of shoreline opposite Eilean Amalaig island.

Weather

No rainfall was recorded 48 hours prior to the first survey day however; light rain began around 17:00 on Monday evening and continued throughout the night. The majority of the first survey day was warm at around 14°C with a light south westerly breeze. It was overcast with cloud cover of 90%. The sea state was calm.

On the second day of the survey there had been overnight rainfall which began again by 13:00 the next day. There was 100% cloud cover and a light south westerly wind. Temperature was 12°C and the sea state was choppy.

Stakeholder engagement during the survey

Prior to the survey, the sampling officer Mr Ewan MacDougall was very helpful and provided useful information regarding the survey site and fishery. Unfortunately the survey team were unable to meet with Mr MacDougall during the course of the survey.

On the first day of the survey (22nd September), the survey team met with Inverlussa Marine Services Ltd Director Mr Douglas Wilson and Operations Director Mr Ben Wilson. Both were very helpful and provided further details regarding the site. Mr Ben Wilson kindly took the survey team out on his boat to collect seawater and shellfish samples and to collect CTD cast data. Mr Wilson also kindly agreed to take the survey team out on his boat to complete sections of the shoreline survey which were inaccessible by land.

Fishery

The survey plan listed the following three sites: Inverlussa, SIN: AB-200-056-08, Site 1, SIN: AB-200-057-08 (RMP NM 7027 3018) and Rubha na Faing, SIN AB-202-059-08 (RMP NM 7039 2833). There were actually six sites in total within the production area, which had their names confirmed to the team on the day of the survey by Mr Wilson, as each one was visited: Site 3, associated with waypoints (WP) 1 and 4; Castle Site, associated with WP 5,6,10 and 11; Killean Site, associated with WP 19, 23, 24 and 28; Site 1, associated with WP 29-32; South Ardura associated with WP33, 35-37 and Ardura associated with WP 40, 44-46.

Common mussels (*Mytilus edulis*) are cultivated within the Loch Spelve fishery and harvest normally takes place between the months of March and December. Mr Ben Wilson confirmed that the farm system has been converted from pegged dropper lines to a continuous loop system. It was only possible to obtain one out of the eight shellfish samples required. This was because harvesting was taking place during the course of the survey and a larger boat with winch equipment was unavailable for sampling. The lines which had adult mussels attached were too heavy to be hauled up by the boat which was available to the survey team at the time and so mussels could not be accessed for sampling. On top of this, a large number of the lines which could be hauled up on the smaller boat had only mussel spat settlement and so these also could not be sampled.

The mussel sample taken at waypoint 25 was collected from the top of the dropper at the location detailed in Figure 2.

Mr Ben Wilson noted that during the previous year, the fishery had encountered problems with tubeworms and, to a lesser extent, Eider ducks.

Three mussel lines were observed at Site 3, five lines at Castle Site, six lines at Killean site, four lines at Site 1, six lines at the South Ardura site, and seven lines at the Ardura site.

Sewage Sources

The area of shoreline surrounding the shellfishery at Loch Spelve is largely uninhabited. One house was observed near to the shoreline to the north of the loch at waypoint 66 but it was difficult to tell whether or not it was inhabited and no obvious sewage discharges or septic tanks were visible. There was also a working farm and farm house located to the northwest of Loch Spelve at waypoint 49. Another farm, Ardachoil Farm, was observed further back from the shoreline at waypoint 64; it was however not obvious from the shoreline whether or not the house was inhabited. Again, no sewage discharges or septic tanks were observed from either of these properties.

No public facilities, cafés or restaurants surround Loch Spelve and no obvious sewage discharges were observed during the survey.

Houses and dwellings were observed on the southern shore of Loch Spelve during boat work. However, this shoreline was some distance away and was not part of the shoreline survey. All other areas of shoreline surrounding Loch Spelve which were included in the survey plan did not appear to be inhabited.

Seasonal Population

No official campsites or caravan parks were seen in the area surrounding the production area at Loch Spelve nor were there any hotels, B&Bs or holiday lets observed in the area.

Boats/Shipping

Other than two boats which were working at the Inverlussa mussel farm, no other boats or buoys were observed either in or out of the water during any part of the survey.

Farming and Livestock

Twenty nine sheep were observed in a field next to the farm at waypoint 49 and a further five sheep were in a field at waypoint 58 on the western shore of Loch Spelve. One highland cow was seen in a field next the farm at waypoint 49 and two more were in a field at waypoint 50. Two cows were also observed grazing along the northern shore of Loch Spelve at waypoint 59 and there was further evidence that cattle graze along the shore as droppings were observed at waypoints 66 and 75. A peacock was observed on the farmland at waypoint 49.

Land Use

The land surrounding Loch Spelve appears to be mostly used for rough grazing. There is no evidence of forestry and dwellings are few and very scattered.

Land Cover

The predominant land cover surrounding Loch Spelve is rough pasture with deciduous forest. The land is steep in places with rocky sections immediately next to the shore.

Watercourses

Nine watercourses were marked on the survey map to be sampled during the survey. Eight of these were sampled with an extra sample taken from the watercourse associated with waypoint 64 due to the farmhouse on the shore behind it. The watercourse associated with waypoint 52 could not be sampled as it was completely dried up. Three other watercourses were also observed at waypoints 73, 74 and 77 but were not sampled. The watercourse at waypoint 73 was stagnant with no flow and the watercourses associated with waypoints 74 and 77 were both less than 1 m in width and were not part of the sampling plan.

Of the watercourses sampled the largest was the Lussa River at waypoint 47 and was over 11 m in width. An unnamed watercourse at waypoint 69 was over 6 m in width with all the other watercourses sampled being notably smaller, ranging from 73 cm to 1.83 m in width.

Wildlife/Birds

Wildlife surrounding Loch Spelve was abundant and a large range of birds and wildlife were observed during the course of the survey. Between 100 and 200 herring and common gulls were (*Larus argentatus* and *Larus canus*) observed on the loch at Castle Site at waypoint 9. A further four common gulls were observed at waypoint 62 and a further twenty at waypoint 63. Two more common gulls were seen at waypoint 68. Three cormorants (*Phalacrocorax carbo*) were also seen at waypoint 9 and nine more at waypoint 17. A White-tailed sea eagle (*Haliaeetus albicilla*) was observed flying overhead at waypoint 12 with Mr Ben Wilson noting that it had a nest on the shore not far from the mussel farm. Five common seals (*Phoca vitulina*) in total were noted at waypoints 13 and 14, hauled out on rocks. Four mute swans (*Cygnus olor*), two adult and two juvenile, were feeding on the mussels at waypoint 34. Ten greylag geese (*Anser anser*) were also seen flying

overhead at waypoint 60 and goose droppings were observed on the shoreline at waypoint 66. A further six geese were spotted at waypoint 66, again flying overhead. Two grey herons (*Ardea cinerea*) were recorded at waypoints 61 and another one at each waypoints 63 and 68. A curlew (*Numenius arquata*) was also seen at waypoint 62 and seven rock pipits (Anthus spinoletta) at waypoint 61. One snipe (*Gallinago gallinago*) flew out of the grass at waypoint 74 and seventeen hooded crows (*Corvus corone cornix*) were also observed flying over Loch Spelve at waypoint 75.

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 – 13.

Figure 1. Loch Spelve waypoints.

Figure 2. Loch Spelve samples

Table 1 Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
1	22/09/2014	11:48	NM 69759 30637	169760	730638			Start of survey boat work at Site 3. North end of single mussel line orientated NW-SE direction along shoreline. Single line only, two waypoints taken - one at each end (waypoint 1 and 4).
2	22/09/2014	11:55	NM 69795 30620	169795	730621		LSSW1	Planned seawater sample.
3	22/09/2014	11:55	NM 69801 30612	169801	730613		CTD	CTD cast. Planned mussel sample was not obtained from Site 3 as they were at the seed stage of growth.
4	22/09/2014	11:57	NM 70267 30206	170268	730206			Site 3. South end of single mussel line and confirmed site of RMP. Two boats in water, in operation at time of survey, belonging to mussel farm.
5	22/09/2014	11:59	NM 70510 30163	170511	730163			Castle site. Northwest corner of mussel lines.
6	22/09/2014	12:00	NM 70639 30161	170640	730162			Castle site. North east corner of mussel lines.
7	22/09/2014	12:01	NM 70644 30158	170645	730159		LSSW2	Planned seawater sample.
8	22/09/2014	12:02	NM 70642 30150	170643	730150		CTD	CTD cast. Planned mussel sample was not obtained from Castle site as they were at the seed stage of growth.
9	22/09/2014	12:02	NM 70642 30152	170643	730153	Figure 3		Between one and two hundred herring and common gulls, approximately 80% of which were juveniles, three cormorants both on the mussel buoys and in the water.
10	22/09/2014	12:05	NM 70599 29969	170600	729970			Castle site. Southwest corner of mussel lines.
11	22/09/2014	12:06	NM 70472 29959	170472	729960			Castle site. Southeast corner of mussel lines.
12	22/09/2014	12:08	NM 70947 30094	170947	730094			Start of shoreline observations by boat adjacent to Castle site. One white-tailed sea eagle flying over the loch.
13	22/09/2014	12:15	NM 70635 29208	170636	729209			Three adult common seals and one pup hauled out on the rocks.
14	22/09/2014	12:19	NM 70479 28411	170479	728412	Figure 4		One common seal on west side of Eilean Amalaig island.
15	22/09/2014	12:22	NM 70794 28202	170795	728202	Figure 5	LSFW1	Planned freshwater sample.
16	22/09/2014	12:24	NM 70794 28202	170795	728202	Figure 5		Associated with waypoint 15. Watercourse (Allt Killean) Width = 76 cm, Depth = 7 cm, Flow = 0.178 m/s, SD = 0.006.
17	22/09/2014	12:29	NM 70798 27978	170799	727979			End of east shore survey by boat. Nine cormorants on mussel buoys and in water.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
18	22/09/2014	12:30	NM 70798 27943	170798	727943		LSSW3	Planned seawater sample at Killean site.
19	22/09/2014	12:30	NM 70797 27943	170798	727944			Killean site south east corner of mussel lines.
20	22/09/2014	12:31	NM 70798 27944	170798	727945		CTD	CTD cast.
21	22/09/2014	12:31	NM 70799 27943	170799	727944			Extra waypoint taken in error.
22	22/09/2014	12:34	NM 70798 27923	170799	727924			Planned mussel sample was not obtained from this site as the lines were too heavy to lift with the winch on the boat that the team were taken out on.
23	22/09/2014	12:35	NM 70761 27890	170761	727891			Killean site southwest corner of mussel lines.
24	22/09/2014	12:37	NM 70360 28306	170361	728307			Killean site northwest corner of mussel lines and confirmed site of RMP.
25	22/09/2014	12:40	NM 70363 28313	170363	728313		LSSF1	Unplanned mussel sample taken as no other samples had been obtained from planned sites.
26	22/09/2014	12:40	NM 70362 28313	170363	728313		LSSW4	Unplanned seawater sample taken to accompany the unplanned shellfish sample.
27	22/09/2014	12:40	NM 70363 28312	170363	728313		CTD	CTD cast also to accompany the unplanned shellfish and seawater samples.
28	22/09/2014	12:43	NM 70418 28352	170419	728353			Killean site. Northeast corner of mussel lines.
29	22/09/2014	12:46	NM 70424 28561	170424	728562			Site 1. Southeast corner of mussel lines.
30	22/09/2014	12:46	NM 70372 28587	170373	728588			Site 1. Southwest corner of mussel lines.
31	22/09/2014	12:49	NM 70640 29373	170641	729374			Site 1. Northeast corner of mussel lines.
32	22/09/2014	12:50	NM 70574 29371	170575	729371			Site 1. Northwest corner of mussel lines.
33	22/09/2014	12:53	NM 70033 29144	170033	729144			Ardura South site. Southeast corner of mussel lines.
34	22/09/2014	12:55	NM 70075 29368	170076	729369	Figure 6		Four mute swans (two adult, two juvenile) in water close to mussel lines, eating mussel spat.
35	22/09/2014	12:55	NM 70079 29387	170080	729387			Ardura South site. Northeast corner of mussel lines.
36	22/09/2014	12:56	NM 69969 29374	169970	729374			Ardura South site. Northwest corner of mussel lines.
37	22/09/2014	12:57	NM 69904 29150	169904	729150			Ardura South site. Southwest corner of mussel lines.
38	22/09/2014	12:59	NM 69824 28938	169824	728939			Start of shoreline survey by boat of west side of Loch Spelve.
39	22/09/2014	13:05	NM 69731 30041	169731	730042			End of shoreline survey by boat.
40	22/09/2014	13:06	NM 69933 29969	169934	729970			Ardura site. Northwest corner of mussel lines.
41	22/09/2014	13:07	NM 69938 29951	169938	729952		LSSW5	Ardura site, planned seawater sample.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
42	22/09/2014	13:08	NM 69938 29951	169938	729952		CTD	CTD cast.
43	22/09/2014	13:08	NM 69937 29954	169938	729954			Planned mussel sample was not obtained from Ardura site as they were at the seed stage of growth.
44	22/09/2014	13:14	NM 69955 29740	169956	729740			Ardura site. Southwest corner of mussel lines.
45	22/09/2014	13:16	NM 70085 29706	170085	729707			Ardura site. Southeast corner of mussel lines.
46	22/09/2014	13:17	NM 70076 29911	170077	729911			Ardura site. Northeast corner of mussel lines.
47	22/09/2014	14:32	NM 68887 30876	168887	730876	Figure 7	LSFW2	Planned freshwater sample.
48	22/09/2014	14:36	NM 68886 30886	168886	730887	Figure 7		Associated with waypoint 47. Watercourse (Lussa River) width = 11.81 m, Depth 1 = 29 cm, flow 1 = 0.259 m/s, SD1 = 0.017. Depth 2 = 47 cm, flow 2 = 0.008 m/s, SD 2 = 0.004.
49	22/09/2014	14:56	NM 68442 30613	168442	730614			Twenty nine sheep in field and one highland cow by farm with house and barn. One peacock sitting on the fence.
50	22/09/2014	15:19	NM 68805 30787	168806	730788			Two highland cows in field next to watercourse.
51	22/09/2014	15:28	NM 68935 30765	168935	730765			Dried up stream bed no water observed.
52	22/09/2014	15:32	NM 68966 30621	168966	730621	Figure 8		Dried up stream bed no water observed. Planned freshwater sample not obtained.
53	22/09/2014	15:41	NM 69104 30270	169104	730271		LSFW3	Planned freshwater sample.
54	22/09/2014	15:44	NM 69101 30270	169102	730271			Associated with waypoint 53. Unnamed watercourse running into loch. Width = 73 cm, Depth = 8 cm, Flow = 0.028 m/s, SD = 0.005.
55	22/09/2014	15:56	NM 69258 30182	169258	730182		LSFW4	Planned freshwater sample.
56	22/09/2014	15:56	NM 69258 30180	169259	730181			Associated with waypoint 55. Unnamed watercourse running onto shore. Width = 1.36 m, Depth = 12 cm, Flow = 0.008 m/s, SD = 0.002.
57	22/09/2014	16:06	NM 69427 30207	169427	730208			Steep rocky shore no access.
58	22/09/2014	16:19	NM 69039 30524	169040	730525			Five sheep in field next to shore. End of west side of shoreline survey.
59	23/09/2014	11:32	NM 69967 30940	169967	730941	Figure 9		Start of north and east side shoreline survey. Two cows on shore.
60	23/09/2014	11:34	NM 70051 30933	170052	730934			Ten greylag geese flying over the loch.
61	23/09/2014	11:42	NM 70022 30708	170023	730708			Two grey herons at water's edge, seven rock pipits on shore.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
62	23/09/2014	11:50	NM 70114 30500	170114	730500			One curlew, four common gulls.
63	23/09/2014	12:12	NM 70442 30462	170443	730463			Twenty common gulls, one grey heron.
64	23/09/2014	12:30	NM 70481 30943	170482	730944	Figure 10	LSFW5	Unplanned freshwater sample taken from watercourse running close to farm.
65	23/09/2014	12:31	NM 70481 30944	170481	730944	Figure 10		Associated with waypoint 64. Unnamed watercourse running into loch with farm house further back from shore. Width = 85 cm, Depth = 12 cm, Flow = 0.006 m/s, SD = 0.010.
66	23/09/2014	12:43	NM 70676 30953	170677	730953			Goose droppings and cow droppings observed on shore. Six greylag geese observed flying over the loch. One house on shore behind watercourse.
67	23/09/2014	12:47	NM 70730 30952	170731	730953		LSFW6	Planned freshwater sample.
68	23/09/2014	12:48	NM 70730 30953	170731	730954			Associated with waypoint 67. Watercourse (Abhainn an t-Sidhean) running into loch from direction of road. Width = 1.83 m, Depth = 29 cm, Flow = 0.057 m/s, SD = 0.005. Two common gulls and one grey heron on shore.
69	23/09/2014	12:55	NM 70855 30957	170856	730958	Figure 11	LSFW7	Planned freshwater sample.
70	23/09/2014	12:56	NM 70855 30957	170856	730958	Figure 11		Associated with waypoint 69. Unnamed watercourse running into loch. Width = 6.74 m, Depth 1 = 8 cm, Flow 1 = 0.091 m/s, SD 1 = 0.004. Depth 2 = 6 cm, Flow 2 = 0.057 m/s, SD 2 = 0.004.
71	23/09/2014	13:17	NM 71195 30868	171196	730868		LSFW8	Planned freshwater sample.
72	23/09/2014	13:17	NM 71196 30868	171196	730869			Associated with waypoint 71. Unnamed watercourse running from hillside into loch. Width = 1.21 m, Depth = 5 cm, Flow = 0.074 m/s, SD = 0.004.
73	23/09/2014	13:29	NM 71287 30741	171288	730741			Small stream, not on sample plan, stagnant, no sample taken.
74	23/09/2014	13:32	NM 71266 30681	171267	730682	Figure 12		Small stream, not on sample plan, very little flow, no sample taken. One snipe flew out of grass.
75	23/09/2014	13:48	NM 71127 30096	171127	730097			Cow droppings on shore, seventeen hooded crows flying over loch.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
76	23/09/2014	13:50	NM 71135 30064	171135	730065	Figure 13		Small stream, sampled later (see waypoint 78), another stream was observed a few metres ahead and this was visited to ensure it was the correct stream to sample regarding the sample plan.
77	23/09/2014	13:56	NM 71134 29984	171134	729984			Small stream, not on sample plan, not sampled as less than 1 m width.
78	23/09/2014	13:59	NM 71137 30064	171138	730065	Figure 13	LSFW9	Planned freshwater sample.
79	23/09/2014	13:59	NM 71137 30064	171138	730065	Figure 13		Associated with waypoint 76 and 78. Watercourse (Allt na Teangaidh) running downhill into loch. Width = 1.05 m, Depth = 14 cm, Flow = 0.005 m/s, SD = 0.003.

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

Sampling

Seawater and freshwater samples were collected at the sites marked in Figure 2. An extra freshwater sample was taken at waypoint 64 due to its proximity to a farm house. A planned freshwater sample associated with waypoint 52 could not be obtained as the watercourse had dried up.

One common mussel sample was taken at waypoint 25. It was not possible for eight mussel samples to be collected as required. This was because harvesting was taking place during the course of the survey and a larger boat with winch equipment was unavailable for use by the survey team for sampling. On top of this, a large number of the lines which could be hauled up on the smaller boat had only mussel spat settlement and so these also could not be sampled.

The mussel sample taken at waypoint 25 was collected from the top of the dropper at the location detailed in Figure 2.

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, seawater samples and shellfish samples were received by GSS within 48 hours of collection. The sample temperature on arrival at GSS ranged between 3.7°C and 6.4°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	22/09/2014	LSSW1	NM 69795 30620	Seawater	0	34.33
2	22/09/2014	LSSW2	NM 70644 30158	Seawater	0	34.51
3	22/09/2014	LSFW1	NM 70794 28202	Freshwater	430	-
4	22/09/2014	LSSW3	NM 70798 27943	Seawater	0	34.51
5	22/09/2014	LSSW4	NM 70362 28313	Seawater	0	34.33
6	22/09/2014	LSSW5	NM 69938 29951	Seawater	0	34.51
7	22/09/2014	LSFW2	NM 68887 30876	Freshwater	100	-
8	22/09/2014	LSFW3	NM 69104 30270	Freshwater	20	-
9	22/09/2014	LSFW4	NM 69258 30182	Freshwater	<10	-
10	23/09/2014	LSFW5	NM 70481 30943	Freshwater	10	-
11	23/09/2014	LSFW6	NM 70730 30952	Freshwater	90	-
12	23/09/2014	LSFW7	NM 70855 30957	Freshwater	110	-
13	23/09/2014	LSFW8	NM 71195 30868	Freshwater	110	-
14	23/09/2014	LSFW9	NM 71137 30064	Freshwater	<10	-

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	Sample depth (m)	E. coli (MPN/100g)
1	22/09/2014	LSSF1	NM 70363 28313	Shellfish	0 m (top of dropper)	<18

Salinity Profiles

Five CTD profiles were taken at locations detailed in Figure 2. The gathered data will be sent to Cefas as agreed previously on a separate Excel sheet.

Photographs – Loch Spelve

Figure 3. Between one and two hundred herring and common gulls, approximately 80% of which were juveniles. Associated with waypoint 9.

Figure 4. One common seal on west side of Eilean Amalaig island. Associated with waypoint 14.

Figure 5. Allt Killean watercourse. Associated with waypoints 15 & 16 and freshwater sample LSFW1.

Figure 6. Four mute swans (two adult, two juvenile) in water close to mussel lines. Associated with waypoint 34.

Figure 7. Lussa River. Associated with waypoints 47 & 48 and freshwater sample LSFW2.

Figure 8. Dried up river bed. Planned freshwater sample not obtained. Associated with waypoint 52.

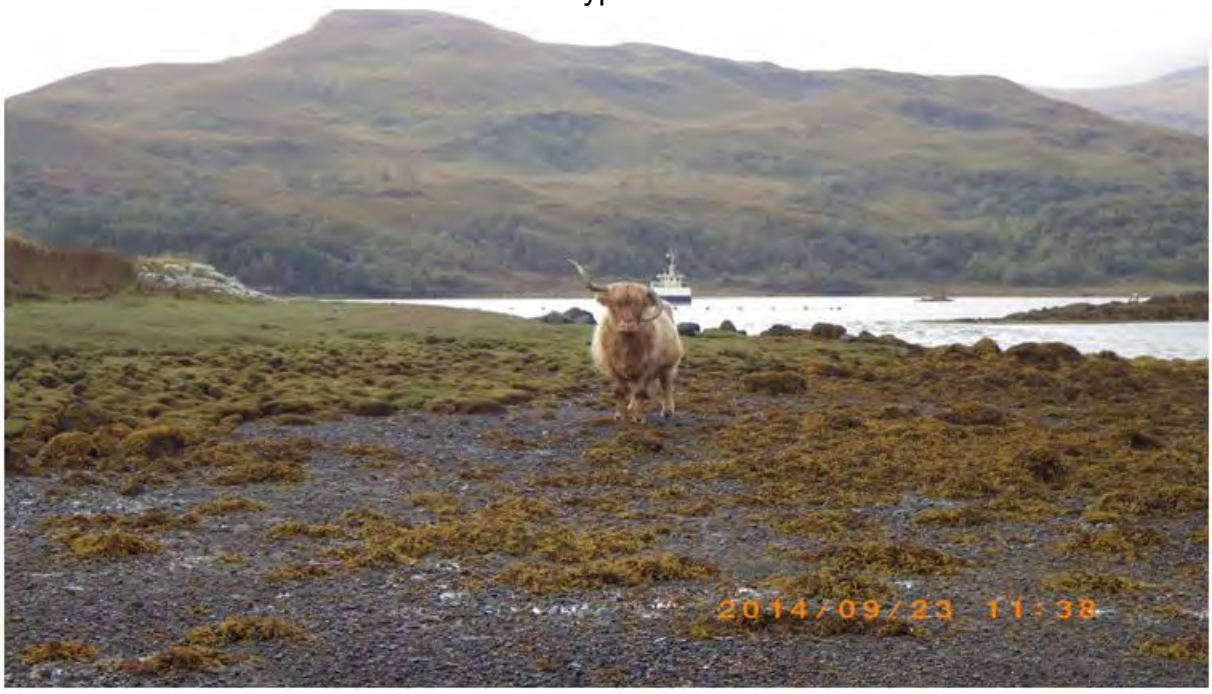

Figure 9. Highland cow on shore. Associated with waypoint 59.

Figure 10. Unnamed watercourse running into loch. Associated with waypoints 64 & 65. Site of unplanned freshwater sample LSFW5.

Figure 11. Unnamed watercourse running into loch. Associated with waypoints 69 & 70 and freshwater sample LSFW7.

Figure 12. Small stream, not on sample plan. Very little flow, no sample taken.

Figure 13. Allt na Teangaidh watercourse running downhill into loch. Associated with waypoint 76 and 78 and freshwater sample LSFW9.

6. Loch Spelve CTD data

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

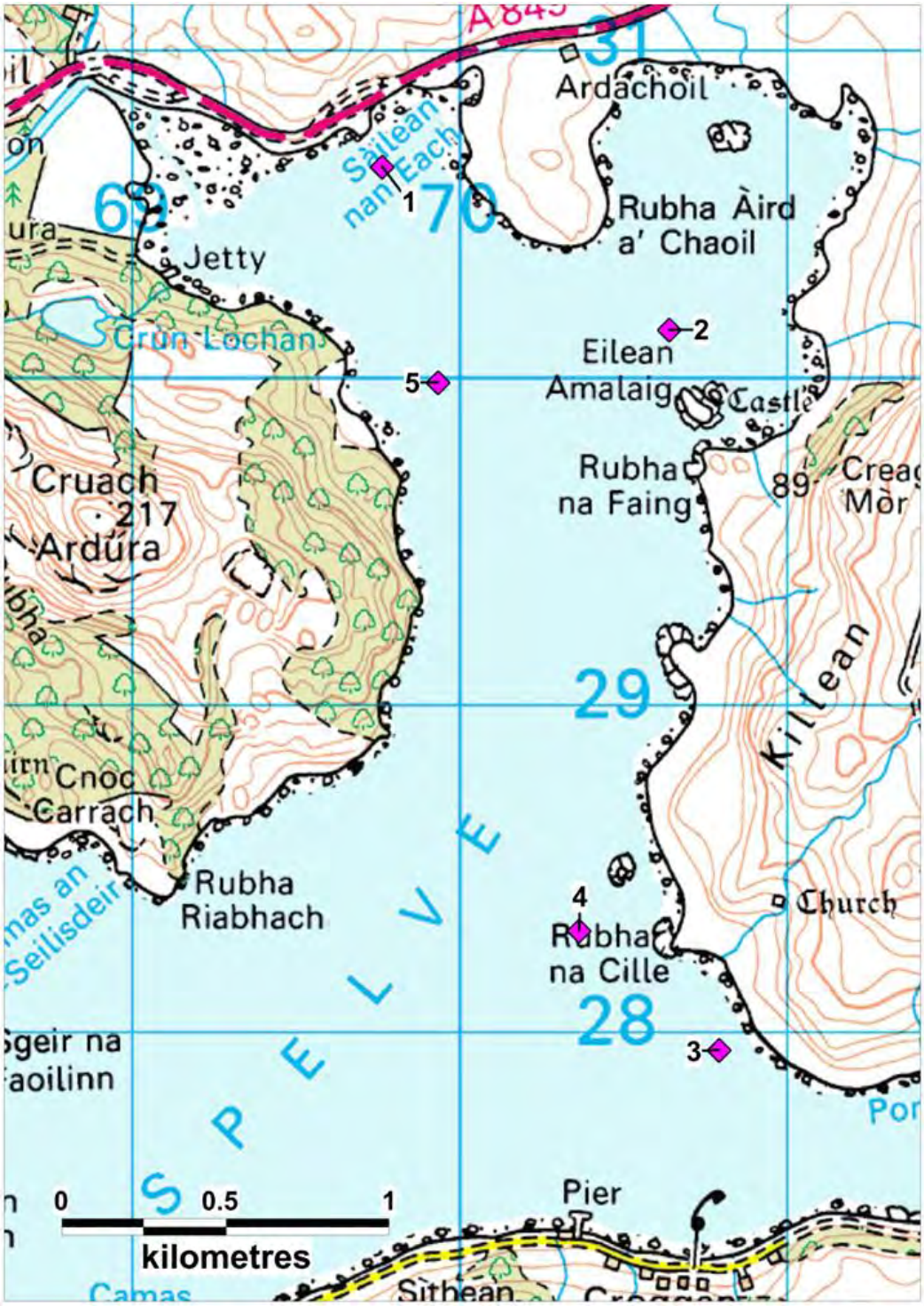

Figure A6.1 Location of CTD cast

CAST 1
Data Header

% Device	10G100653
% File name	10G100653_20140922_105404
% Cast time (local)	22/09/2014 11:54
% Sample type	Cast
% Cast data	Processed
% Location source	GPS
% Start latitude	56.4117342
% Start longitude	-5.7338197
% Start GPS horizontal error(Meter)	3.140000105
% Start GPS vertical error(Meter)	4.340000153
% Start GPS number of satellites	6
% Cast duration (Seconds)	65.6
% 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)
0.14907571	14.29287293	33.64232798
0.447212812	14.29569247	33.62921125
0.745358096	14.29390932	33.61315088
1.043505824	14.29255048	33.60361123
1.341645628	14.2969502	33.68162147
1.639777934	14.29278276	33.66751415
1.937910433	14.29564997	33.67658188
2.236041137	14.29364751	33.68077625
2.534170284	14.28785852	33.68537378
2.832299921	14.29163568	33.67289158
3.130430803	14.28244223	33.66984712
3.428559607	14.27371959	33.68355343
3.726685671	14.25575258	33.68400224
4.024811331	14.24205132	33.67554779
4.322935896	14.21409802	33.67944719
4.621059508	14.19617345	33.66856783
4.91918264	14.18263349	33.67220757
5.21730431	14.17168796	33.67196372
5.515424598	14.16209399	33.67597579
5.81354403	14.15308027	33.67156799
6.111662688	14.14969965	33.67654602
6.40978077	14.14615112	33.67185492
6.707900487	14.14472418	33.65767482
7.006021697	14.1422616	33.65453558
7.304142577	14.13908847	33.65612124
7.602725293	14.13679208	33.66451042

CAST 2

Data Header

% Device	10G100653
% File name	10G100653_20140922_110207
% Cast time (local)	22/09/2014 12:02
% Sample type	Cast
% Cast data	Processed
% Location source	GPS
% Start latitude	56.4076915
% Start longitude	-5.7191965
% Start GPS horizontal error(Meter)	4.03000021
% Start GPS vertical error(Meter)	4.940000057
% Start GPS number of satellites	6
% Cast duration (Seconds)	97
% 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)
0.149092663	14.34920159	33.5072033
0.447261176	14.3457615	33.51437291
0.745434216	14.34447165	33.50908668
1.043606913	14.33710606	33.5120993
1.341779111	14.33353767	33.50758405
1.639951905	14.32977179	33.50181492
1.938125358	14.33086903	33.49802621
2.236298582	14.32576998	33.49980416
2.534471377	14.32283015	33.49667636
2.832643785	14.31833505	33.49827242
3.130814628	14.31503167	33.50551555
3.428984181	14.31085037	33.50476556
3.727152963	14.30044457	33.5054272
4.025320103	14.29224972	33.51135997
4.323485818	14.27590623	33.50845792
4.621650542	14.25536819	33.50717041
4.919813787	14.23004049	33.50616837
5.217975896	14.21902372	33.50442895
5.516137112	14.20860943	33.50533258
5.814297455	14.20231039	33.5046916
6.112457139	14.20077363	33.50611229
6.410616003	14.19473008	33.50698047
6.708774141	14.19088111	33.50691699
7.006931284	14.19197024	33.51213817

7.305087444	14.19073509	33.51266542
7.603243397	14.19410127	33.51160301
7.901398793	14.19598751	33.51609137
8.19955295	14.19563562	33.52009133
8.497706062	14.19706034	33.52273523
8.795859103	14.19751005	33.51827124
9.094011852	14.19569447	33.52199945
9.312607743	14.19536427	33.51942292

CAST 3

Data Header

% Device	10G100653
% File name	10G100653_20140922_113112
% Cast time (local)	22/09/2014 12:31
% Sample type	Cast
% Cast data	Processed
% Location source	GPS
% Start latitude	56.3880302
% Start longitude	-5.7148145
% Start GPS horizontal error(Meter)	6.889999866
% Start GPS vertical error(Meter)	9.130000114
% Start GPS number of satellites	7
% Cast duration (Seconds)	165.4
% Samples per second	5
Calibration Date	March 2013
Calibration offset for Temperature	-0.033
Calibration offset for Salinity	0.029

CTD data (calibration offsets applied)

Depth (Meter)	Temperature (Celsius)	Salinity (Practical Salinity Scale)
0.14910118	14.40760605	33.45600753
0.447283563	14.40439344	33.45270128
0.745472683	14.40669831	33.45215208
1.043659986	14.40588215	33.46634126
1.341845726	14.40638669	33.46302644
1.640031475	14.40476819	33.46299565
1.938216129	14.40589909	33.46968226
2.236399431	14.40143501	33.47117515
2.534582312	14.39959123	33.46873423
2.832765308	14.39486476	33.46539135
3.130947924	14.39631876	33.46826037
3.429129941	14.38832553	33.46596786
3.727310998	14.38568504	33.47094189
4.025491727	14.38575547	33.46523197

4.323671984	14.37936354	33.47044356
4.621851423	14.37502193	33.46661717
4.920030411	14.37265927	33.46967337
5.218208647	14.37426689	33.47013674
5.516386467	14.37191855	33.47022391
5.814563585	14.36616458	33.47120923
6.112739992	14.36133896	33.47069613
6.410915511	14.3544972	33.47296483
6.70909012	14.3550151	33.47411279
7.007263694	14.34881683	33.47766471
7.305435772	14.33801266	33.47983137
7.603605991	14.32125196	33.48372661
7.901772884	14.30568385	33.49765854
8.199938276	14.30569019	33.48988645
8.498104129	14.30697768	33.49094197
8.796268462	14.29708151	33.49810848
9.094431146	14.29330792	33.49894668
9.392592601	14.29217138	33.5047465
9.690753157	14.29174264	33.5035716
9.988912607	14.29008456	33.51107603
10.2838528	14.29138408	33.51274261

CAST 4

Data Header

% Device	10G100653
% File name	10G100653_20140922_114024
% Cast time (local)	22/09/2014 12:40
% Sample type	Cast
% Cast data	Processed
% Location source	GPS
% Start latitude	56.3910916
% Start longitude	-5.7220549
% Start GPS horizontal error(Meter)	14.43999958
% Start GPS vertical error(Meter)	17.54999924
% Start GPS number of satellites	4
% Cast duration (Seconds)	80.6
% 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)
0.14909245	14.35304474	33.51356247
0.447259986	14.34680774	33.51568467

0.745433155	14.35336073	33.51003343
1.04360577	14.34770574	33.51790943
1.341776556	14.34540596	33.52117865
1.639946949	14.34701991	33.51827448
1.938117865	14.34757336	33.5141471
2.236289629	14.34385283	33.50688555
2.534460273	14.34527559	33.52054054
2.832629307	14.34535467	33.51868028
3.130798539	14.3421171	33.51495018
3.428967256	14.34422654	33.51999214
3.727135286	14.3444958	33.5187703
4.02530303	14.34209836	33.51899066
4.323470095	14.33724718	33.51987614
4.621635814	14.33371821	33.52572628
4.919800442	14.33266545	33.52538479
5.217965252	14.33091402	33.52037355
5.516129776	14.32600157	33.52314358
5.814293043	14.32200268	33.52618714
6.112456015	14.3190337	33.52089332
6.410618243	14.31505719	33.52796398
6.708779636	14.31130622	33.52325382
7.006941048	14.31157538	33.52388314
7.305101756	14.30495984	33.52482722
7.603261308	14.30352765	33.52902989
7.901419806	14.30017658	33.52993974
8.199577894	14.29968242	33.52867111
8.497735856	14.30264266	33.52878519
8.703477874	14.30247454	33.52951824

CAST 5

Data Header

% Device	10G100653
% File name	10G100653_20140922_121135
% Cast time (local)	22/09/2014 13:11
% Sample type	Cast
% Cast data	Processed
% Location source	GPS
% Start latitude	56.4059091
% Start longitude	-5.7304859
% Start GPS horizontal error(Meter)	7.869999886
% Start GPS vertical error(Meter)	9.050000191
% Start GPS number of satellites	5
% Cast duration (Seconds)	50
% Samples per second	5
Calibration Date	March 2013
Calibration offset for Temperature	-0.033

Calibration offset for Salinity	0.029

CTD data (calibration offsets applied)

Depth (Meter)	Temperature (Celsius)	Salinity (Practical Salinity Scale)
0.149100277	14.31915941	33.43640112
0.447280398	14.30882406	33.44375258
0.745463238	14.29365468	33.45878472
1.043642081	14.28277623	33.46927599
1.341818809	14.28091688	33.47118486
1.63999468	14.27808418	33.47268091
1.938170566	14.27512755	33.46649554
2.236345946	14.26843401	33.47160283
2.534520302	14.26194459	33.46906526
2.832693712	14.24858526	33.47165679
3.130866331	14.23646383	33.46620453
3.429039135	14.227115	33.46121126
3.727210942	14.21663105	33.4667184
4.025380498	14.20487772	33.47225765
4.323548854	14.20207839	33.47048451
4.621716769	14.200854	33.47212464
4.919883733	14.19814475	33.47492552
5.218049852	14.20049758	33.47660152
5.516214924	14.20356	33.48275264
5.814379553	14.2086851	33.47980516
6.112542776	14.22115922	33.49710744
6.410704219	14.22712365	33.49771161
6.708865593	14.23790948	33.49932329
7.007025889	14.24644255	33.50960544
7.305183904	14.25453616	33.521215
7.6033408	14.2573483	33.51958172
7.901498678	14.25658874	33.51006615
8.199657398	14.25834196	33.50939428
8.497818093	14.25382554	33.48876006
8.795979224	14.22337846	33.49301566
9.042432714	14.21816828	33.48203797