Scottish Sanitary Survey Report

Sanitary Survey Report
Loch Laxford
HS-167
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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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Appendices

I. Executive Summary

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

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

Loch Laxford is a sea loch in the northwest of Scotland. It is complex in both topography and bathymetry. The classified production area is comprised of six long-line mussel farms located within both the main loch and within Loch a' Chadh-Fi, which adjoins it.

Sources of human faecal contamination are principally associated with the settlements of Ardmore, Fanagmore and Foindle. Although many of the septic tanks are consented to discharge to soakaway, a number were identified that discharge to the marine environment. There is likely to be a greater overall input to the loch in the vicinity of Ardmore in the spring and summer due to the presence of visitor accommodation. Contamination arising from animal sources is principally associated with sheep, located around Loch a' Chadh-Fi, and geese and seabirds, noted around the loch but with significant populations near the mouth. Estimated *E. coli* loadings in watercourses were low to moderate at the time of the shoreline survey.

The estimated particle transport distance over a single ebb or flood tide was estimated to be approximately 1 km, with the residual transport over a full tidal cycle being of the order of 0.5 km. From this perspective, many of the mussel farm areas are at, or beyond the limit of transport from identified point sources or watercourses and may only be exposed to intermittent diffuse pollution. The exception is the Loch a' Chadh-Fi, Ardmore site which is close to sources of contamination from both humans and sheep.

A bacteriological survey undertaken at three points showed higher mean and maximum levels at Loch a' Chadh-Fi, Ardmore than at two other sites.

It is recommended that the production area boundaries be revised to exclude known concentrations of point and diffuse sources where this will not impact on the extent of the current fisheries. It is also recommended that the RMP is moved to the Loch a' Chadh-Fi, Ardmore site to reflect the risk of contamination that has been identified at that location. Further details are given in the sampling plan.

II. Sampling Plan

Production Area	Loch Laxford
Site Name	Loch a' Chadh-Fi, Ardmore
SIN	HS-167-318-08
Species	Common mussels
Type of Fishery	Longline
NGR of RMP	NC 2099 5115
East	220990
North	951150
Tolerance (m)	40
Depth (m)	1-3
Method of Sampling	Hand
Frequency of Sampling	Monthly
Local Authority	Highland Council
Authorised Sampler(s)	Anne Grant
Local Authority Liaison Officer	Alan Yates
Production area	The recommended area is therefore the area within the lines drawn between NC 1723 5100 and NC 1879 5100 and between NC 2200 4800 and NC 2211 4823 and between NC 1956 4921 and NC 2012 4920 and between NC 1808 4995 and NC 1842 4980 and between NC 2219 5105 and NC 2195 5103, and extending to MHWS

III. Report

1. General Description

Loch Laxford is a fjardic sea loch (Joint Nature Conservation Committee, 2014) on the northwest coast of Scotland. The location is shown in Figure 1.1.

Loch Laxford is composed of several smaller lochs and bays but in general has a north westerly aspect and opens to the Atlantic Ocean. The loch has a maximum depth of 46 m but a mean depth of 22 m.

Loch Laxford lies within the Sutherland district of the Highland Council. The area around Loch Laxford is sparsely inhabited with the main population located at the settlements of Foindle and Fanagmore on the southern shore and Ardmore on the west shore of Loch a' Chadh-Fi, with various small clusters of dwellings dispersed around the rest of the loch.

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

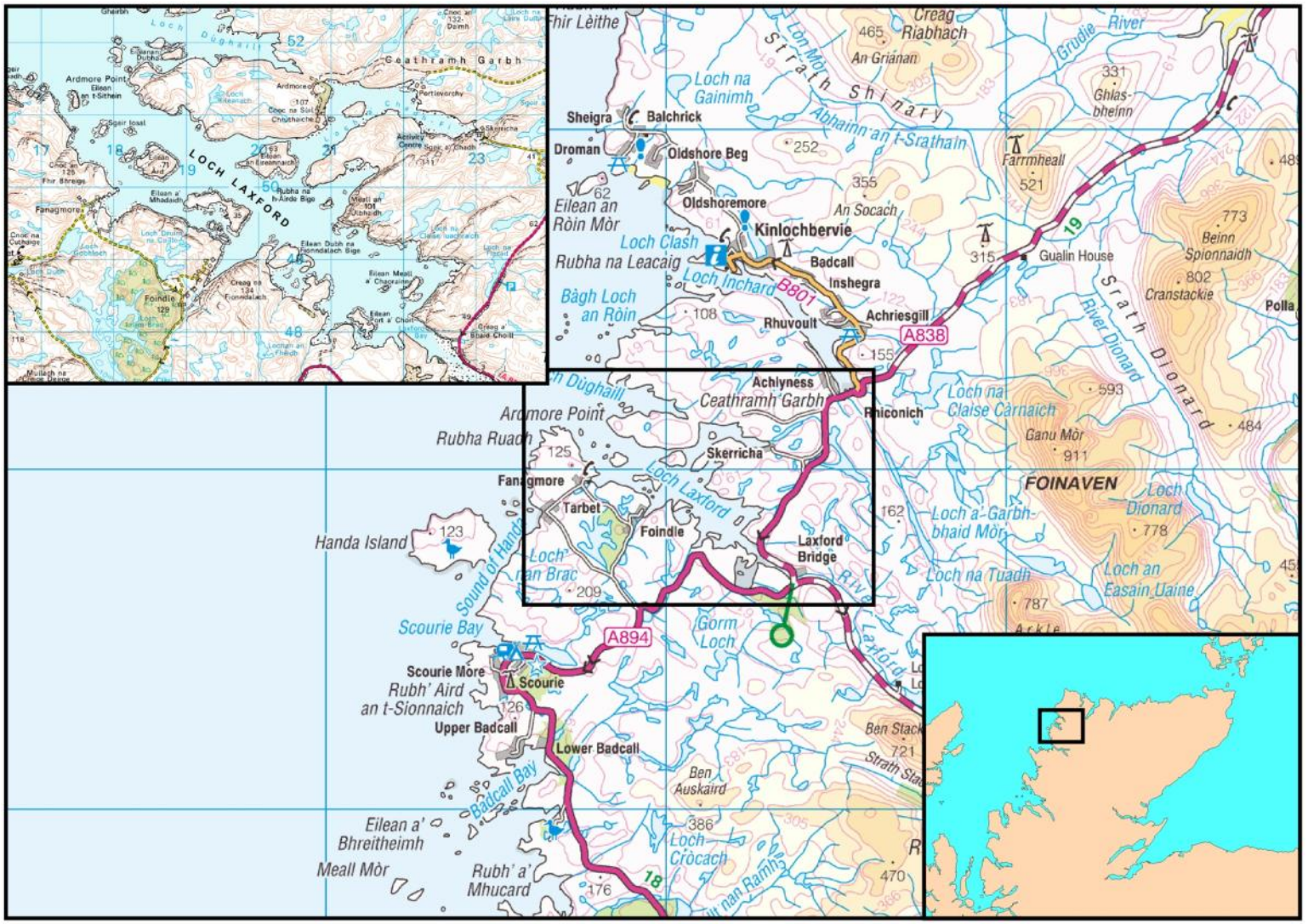

Figure 1.1 Location of Loch Laxford

2. Fishery

The fishery at Loch Laxford is comprised of 6 common mussel farms, all using double-headed long lines. Details of the sites are presented in Table 2.1.

Table 2.1 Loch Laxford shellfish farms

Site	SIN	Species	No. of lines	Dropper length (m)
Baghna Airde Bige	HS-167-316-08	Common mussels	4 (6[2])	6
Eilean Ard	HS-167-317-08	Common mussels	6	8
Loch a' Chadh-Fi, Ardmore	HS-167-318-08	Common mussels	4	6
Sgeir Fhadha	HS-167-319-08	Common mussels	8	6
Weavers Bay	HS-167-320-08	Common mussels	9	6
Eilean an Eireannaich[1]	Not specified	Common mussels	3	5

[1]Site not harvested for several years but identified during the shoreline survey as being back in production.

[2]The harvester identified that there were normally 6 lines present on this site.

The production area boundaries are within the line drawn between NC 1723 5100 and NC 1879 5100 extending inshore to MHWS. The RMP is located at NC 2134 4858 which lies on the Weavers Bay site. The RMP location recorded during the shoreline survey (NC 2132 4862) was approximately 40 m to the northwest of the nominal RMP as identified in FSAS records.

The base for the mussel farm operation is in Weavers Bay. The mussels are harvested from July through to March. The harvester has plans to extend the mussel farms at Sgeir Fhadha and possibly Baghna Airde Bige, and if this was successful, the array at Eilean Ard would be removed.

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

For ease of reference, the Loch a' Chadh-Fi, Ardmore site will be referred to as Loch á Chadh-Fi throughout the text of this report.

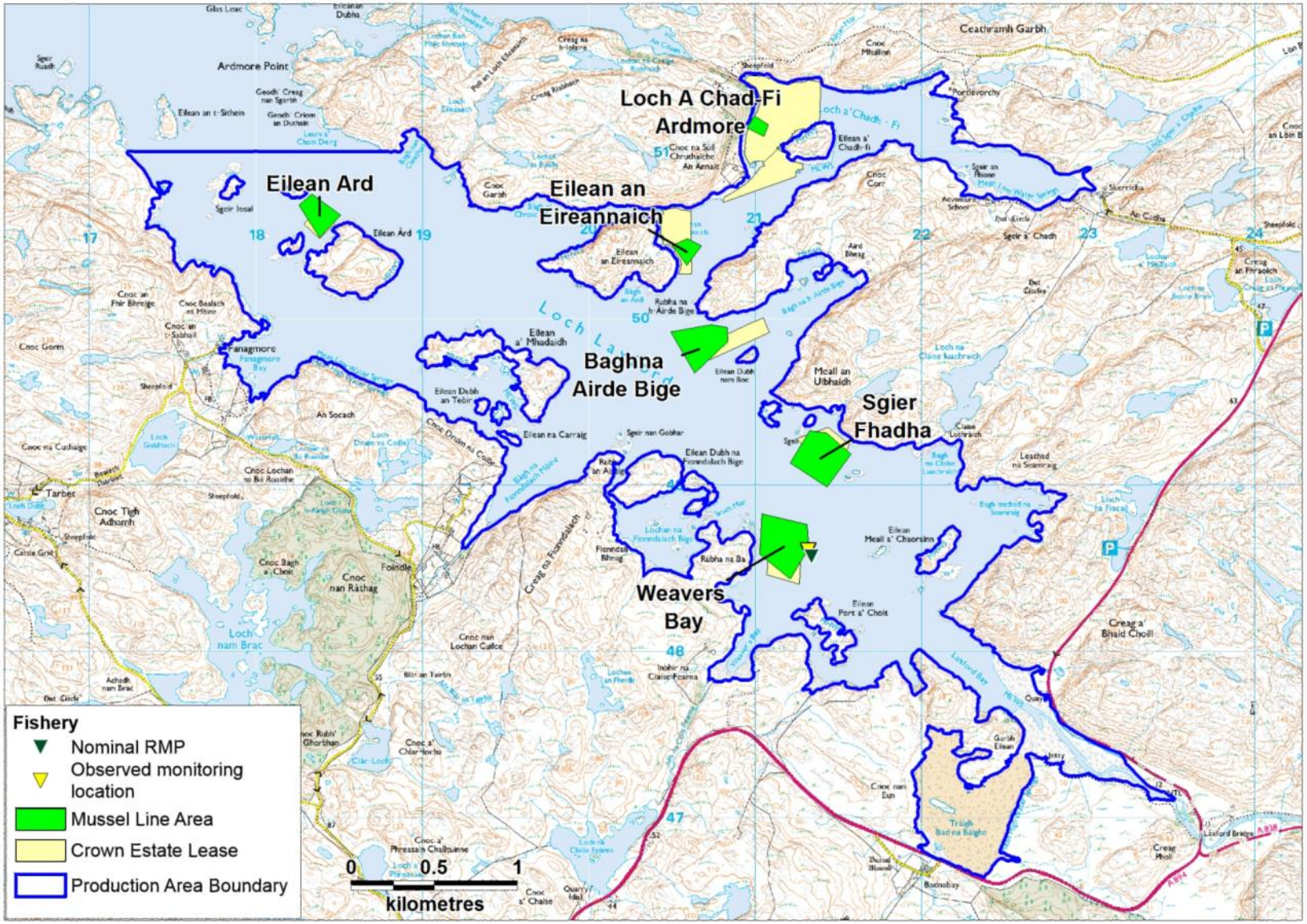

Figure 2.1 Loch Laxford Fishery

3. Human Population

Information was obtained on the population within the vicinity of the Loch Laxford production area from the General Register Office for Scotland. The last census was undertaken in 2011. The census output areas surrounding Loch Laxford are shown in Figure 3.1 thematically mapped by the 2011 population densities. The population density is low overall (< 5 people per km^2) within the output areas bordering the loch. However, the two output areas have vastly different land areas, and the populations within them are not evenly distributed.

Table 3.1 Census output areas and populations – Loch Laxford

Census Output Area ID	Population	Area (km^2)
S00081007	132	351
S00081008	109	32

On the southwestern shore of Loch Laxford there are three small settlements; Fanagmore, Foindle and Badnabay and on the western coastline of Loch a' Chadh-Fi is the small settlement of Ardmore. During the shoreline survey dwellings were observed at Fanagmore, Foindle and Ardmore as shown in Figure 3.1. An outdoor activity centre is located on the south eastern shoreline of Loch a' Chadh-Fi and accommodates 40 pupils plus staff, with camping also available (Ridgeway Adventure, 2014). Two additional self catering cottages are located in Ardmore (Ridgeway, 2003).

A total of eight anchorages are present within the production area (Admiralty Chart 2503). In Loch Laxford, three are located in sheltered bays along the western coastline and two are located in the centre of the loch at the south eastern end, in between the Sgier Fhanda and Weavers Bay mussel farms. Single anchorages are also located north east of the Baghna Airde Bige and Eilean an Eireannaich mussel farms. In Loch a' Chadh-Fi, there is an anchorage located east of the island located in the centre of the loch. During the shoreline survey, a slipway was observed south west of Eilean Ard and a boat was observed on land in the adjacent bay., A large yacht (out of the water) and several smaller boats (in the water) were observed at Ardmore.

Overall, the local population is low and sparsely distributed however in relation to the fisheries, the Loch a' Chadh-Fi mussel farm is likely to be more impacted by human-related sources due to the presence nearby of both dwellings, tourist accommodation including the outdoor activity centre and anchorages. The presence of visitor accommodation and moorings suggests that there is likely to be significant seasonal variation in human population around the loch.

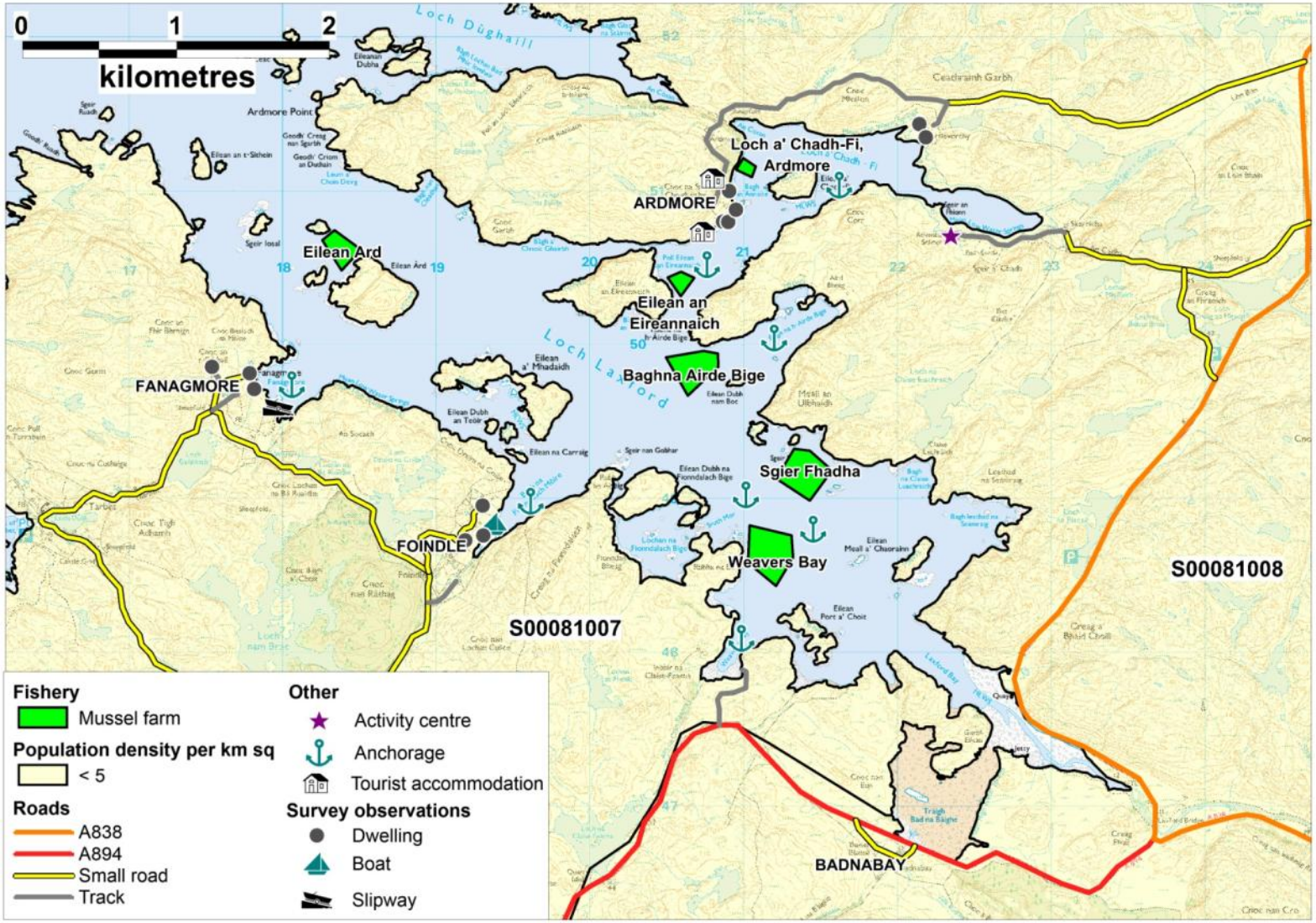

Figure 3.1 Population map for the area around Loch Laxford

4. Sewage Discharges

Information on sewage discharges within 5 km around grid reference NC 2150 4860 (located near the head of the loch) 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 and SEPA reported no community discharges in the request area.

4.2 Consented Private Discharges - SEPA

SEPA provided information regarding consented discharges within the identified request area. Discharges relating to abstraction or engineering works have been excluded from assessment, as they should not contribute to any faecal input to the area. Two private discharges were reported at Tarbet: as this lies outside the confines of Loch Laxford and more than 6 km from the nearest mussel lines, the discharges have been excluded from this assessment. The remaining information related to 15 consents for private sewage discharges located around Loch Laxford: primarily around the settlements of Foindle and Fanagmore on the southern shore of the loch. Other discharges were located at the small settlement of Ardmore at the mouth of Loch a' Chadh – Fi and at individual dwellings around the loch. The consented discharges assessed in this report are listed in Table 4.1 and shown in Figure 4.1. All discharges listed are within 2.5 km of the nearest mussel lines.

Table 4.1. Consented private discharges at Loch Laxford

Licence number	Grid Reference	Discharge Type	Discharging To	PE
CAR/R/1049305	NC 17811 49841	Sewage (Private) Primary	Fanagmore Bay	5
CAR/R/1053587	NC 17527 49852	Sewage (Private) Primary	Soakaway	6
CAR/R/1054961	NC 18973 48417	Sewage (Private) Primary	Soakaway	6
CAR/R/1055096	NC 19174 48714	Sewage (Private) Primary	Soakaway	5
CAR/R/1065055	NC 17927 49462	Sewage (Private) Primary	Soakaway	5
CAR/R/1065236	NC 19258 48819	Sewage (Private) Primary	Soakaway	5
CAR/R/1065253	NC 17870 49780	Sewage (Private) Primary	Fanagmore Bay	5
CAR/R/1065562	NC 17904 49726	Sewage (Private) Primary	Fanagmore Bay	5
CAR/R/1066092	NC 19013 48497	Sewage (Private) Primary	Soakaway	5
CAR/R/1067050	NC 19260 48970	Sewage (Private) Primary	Soakaway	5
CAR/R/1077955	NC 20993 50854	Sewage (Private) Primary	Loch a Chadh	10
CAR/R/1077962	NC 20850 50900	Sewage (Private) Primary	Soakaway	5
CAR/R/1078804	NC 20900 51000	Sewage (Private) Primary	Soakaway	5
CAR/R/1078927	NC 20800 51300	Sewage (Private) Primary	Soakaway	5
CAR/R/1081797	NC 22050 46730	Sewage (Private) Secondary	Allt a Ghleannain	15

PE = Population Equivalent

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

Registration is required for all new properties and upon sale of existing properties. However, there may be unregistered septic tank discharges in addition to those listed.

Four consents related to marine cage fish farms located on the southwest side of the loch. Any toilet facilities on service barges associated with these farms would present an additional point source discharge to the immediate vicinity around the farm, though this is not expected to significantly impact water quality at the mussel farms due to the distances between them.

Shoreline Survey Discharge Observations

Several observations of sewage infrastructure and discharge were recorded during the shoreline survey. These are presented in Table 4.2 below and are shown in Figure 4.1.

Table 4.1 Discharge-associated observations made during the shoreline survey

No.	Date	NGR	Associated Photograph (Appendix 5)	Description
1	14/05/2014	NC 17538 49862		Dwelling with septic tank and soakaway.
2	14/05/2014	NC 17783 49821	Figs. 17&18	One house by shore at road end with pipe into loch beyond steep rocky headland.
3	14/05/2014	NC 17970 49603	Fig. 20	Office has soil pipe external to the east wall. Septic tank was not observed.
4	14/05/2014	NC 19298 48959		Septic tank to soakaway from house on hillside.
5	14/05/2014	NC 19304 48765	Fig. 22	Septic tank with pipe to apparent soak away. Freshwater seepage from grass hillside onto shore. Green algae on upper shore rocks.
6	14/05/2014	NC 19185 48734		Dwelling with soil pipe at rear.
7	14/05/2014	NC 18941 48429		Septic tank with soak away.
8	14/05/2014	NC 22067 46692		Sewage Discharge into watercourse associated with waypoint 106
9	12/05/2014	NC 20820 51404	Fig. 9	Septic tank of pointed local stone, to soakaway. Watercourse running near septic tank
10	12/05/2014	NC 20788 51323		Square, upturned fibreglass tank covering concrete base. No associated outfall pipework observed.
11	12/05/2014	NC 20903 51005	Fig. 7&8	Block work septic tank. No associated onshore outfall observed.
12	12/05/2014	NC 20905 50926		Concrete tank with corrugated iron covering in field below three uphill houses.
13	12/05/2014	NC 20947 50884	Fig. 5&6	Septic tank. Tank effluent carried down beach by 5 cm alkathene pipe.
14	12/05/2014	NC 20898 50805	Fig. 4	Presumed septic tank. Depression downhill in grass with seepage at top of shore. No sign of pipe.
15	12/05/2014	NC 22183 51356	Fig. 11	Septic tank in field. Damaged pipe and tank top with sewage leak onto grass.
16	12/05/2014	NC 22361 50714	Fig. 13	Large concrete septic tank at Ardmore Adventure School with >50 m outfall pipe running into loch.
17	12/05/2014	NC 22338 50760		Unplanned seawater sample, LLSW1, taken close to concrete septic tank outfall approximately 30 m from shore.

Many of the discharges recorded coincide with the location of consented discharges. Information provided by local residents during the shoreline survey suggested that many of the observed septic tanks discharged to soakaway.

Observation 8 related to the secondary treated discharge that enters Allt a Ghleannain a short distance from Traigh Bad na Bàighe.

Two observations (5 and 14) related to seepage from land below soakaways. This suggests an ineffective soakaway resulting in release of undertreated effluent.

Observation 9 related to a watercourse flowing close to the septic tank. Depending on the location of any soakaway, there is the potential for contamination if it is situated too close to the watercourse.

One septic tank in a poor state of repair was reported at Portlevorchy, (Observation 15) with sewage leaking over the ground approximately 30 m from the high tide mark.

A seawater sample (Observation 17) taken from near the outfall of the adventure school septic tank (Observation 16) returned a value of 1 *E. coli* cfu/ 100ml which indicated that there was no significant faecal impact at that location at the time of sampling.

Summary

The primary sewage input to the area is from small private discharges as there are no community discharges. These are principally located in the three centres of habitation around the loch: Ardmore/An Annait, Foindle and Fanagmore. Consented discharges to sea are located in Fanagmore Bay and in Loch a' Chadh-Fi. The input from the adventure school is likely to show marked seasonal variation. Additional pollution may occur from the damaged septic tank at Portlevorchy.

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

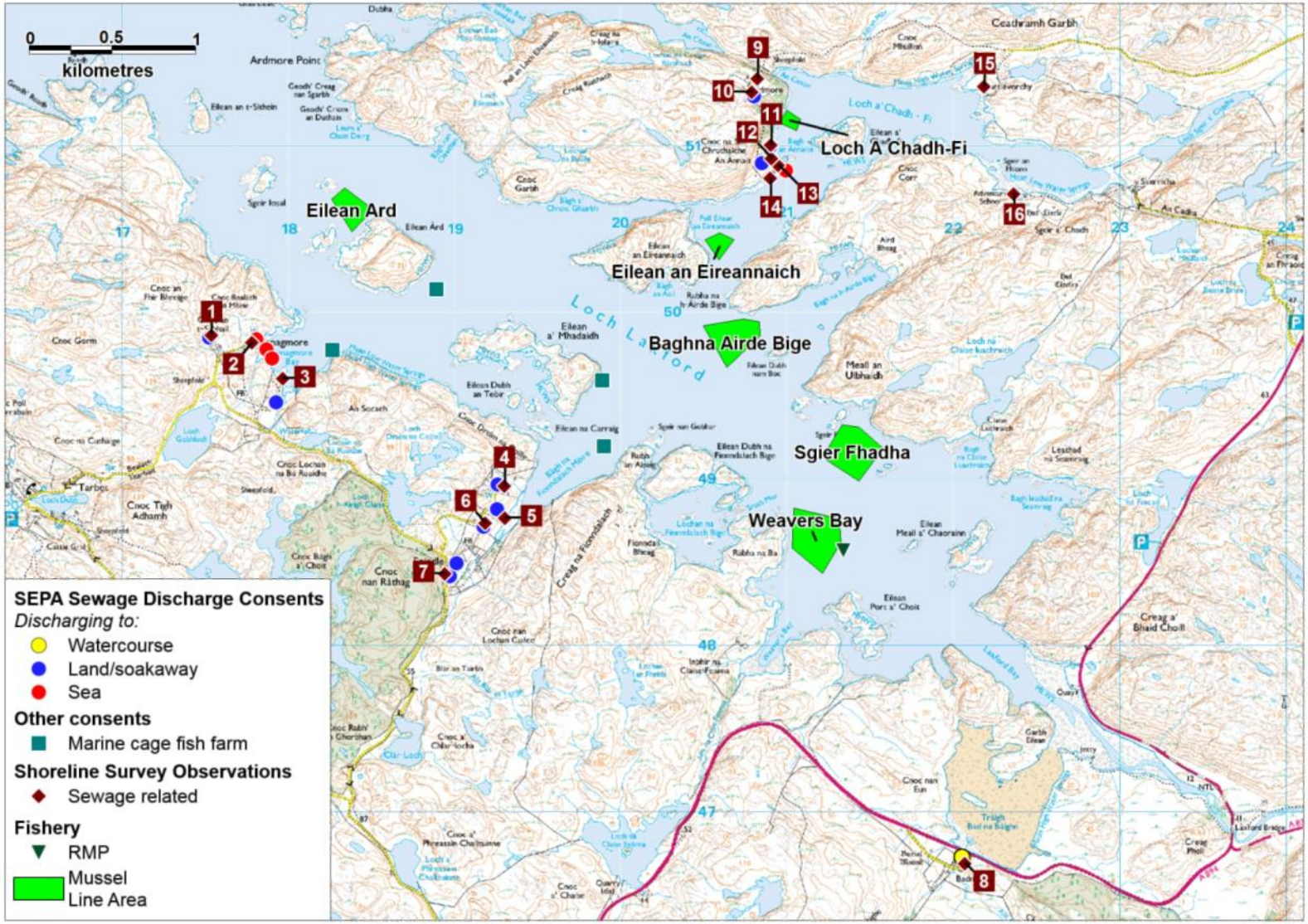

Figure 4.1 Map of discharges at Loch Laxford

5. Agriculture

Information on the spatial distribution of animals on land adjacent to or near the fishery can provide an indication of the potential amount of organic pollution from livestock entering the shellfish farm area. Agricultural census data to parish level for the Eddrachilles parish was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD). 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 less than five holdings, or where two or fewer holdings account for 85% or more of the information, are replaced with an asterisk.

Table 5.1 Livestock numbers in the Eddrachilles agricultural parish 2013

	Eddrachilles	
	577 km^2	
	Holdings	Numbers
Pigs	*	*
Poultry	11	188
Cattle	9	150
Sheep	45	5447
Total horses and ponies	*	*

* data withheld

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

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 12th May 2014. Observations made during the survey are dependent upon the viewpoint of the observer some animals may have been obscured by the terrain. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 5.1.

During the shoreline survey, three herds of sheep were observed grazing on the shoreline of Loch a' Chadh-Fi, including a herd of approximately 17 sheep on the hills west of the Loch a' Chadh-Fimussel farm. Fresh sheep droppings were also observed on the shoreline adjacent to the Loch a' Chadh-Fimussel farm. No other livestock were observed along any other section of the survey route.

A review of publicly available aerial images showed that areas of improved pasture are located inland and on the coast of Loch a' Chadh-Fi and also on the southern coast of Loch Laxford (Bing Maps, accessed 26/06/2014). The areas of improved pasture surrounding Loch a' Chadh-Fi correspond with the locations of the livestock observed during the shoreline survey. Areas identified from the aerial images as likely improved pasture are shown in Figure 5.1. A sheep dip was identified by SEPA on the eastern coastline of Loch a' Chadh-Fi. Numbers of sheep are expected to be approximately double during the spring and summer months when lambs are present. Any contributions of faecal contamination from livestock grazing in the area would potentially affect those shellfish grown in shallower water closest to the shore. The largest concentration of livestock was observed on the hillside west of the Loch a' Chadh-Fi, Ardmore mussel farm. Based on the distribution of animals and pasture seen in satellite images, impacts may be expected to be greatest at the Loch a' Chadh-Fi and Eilean an Eireannaich mussel farms.

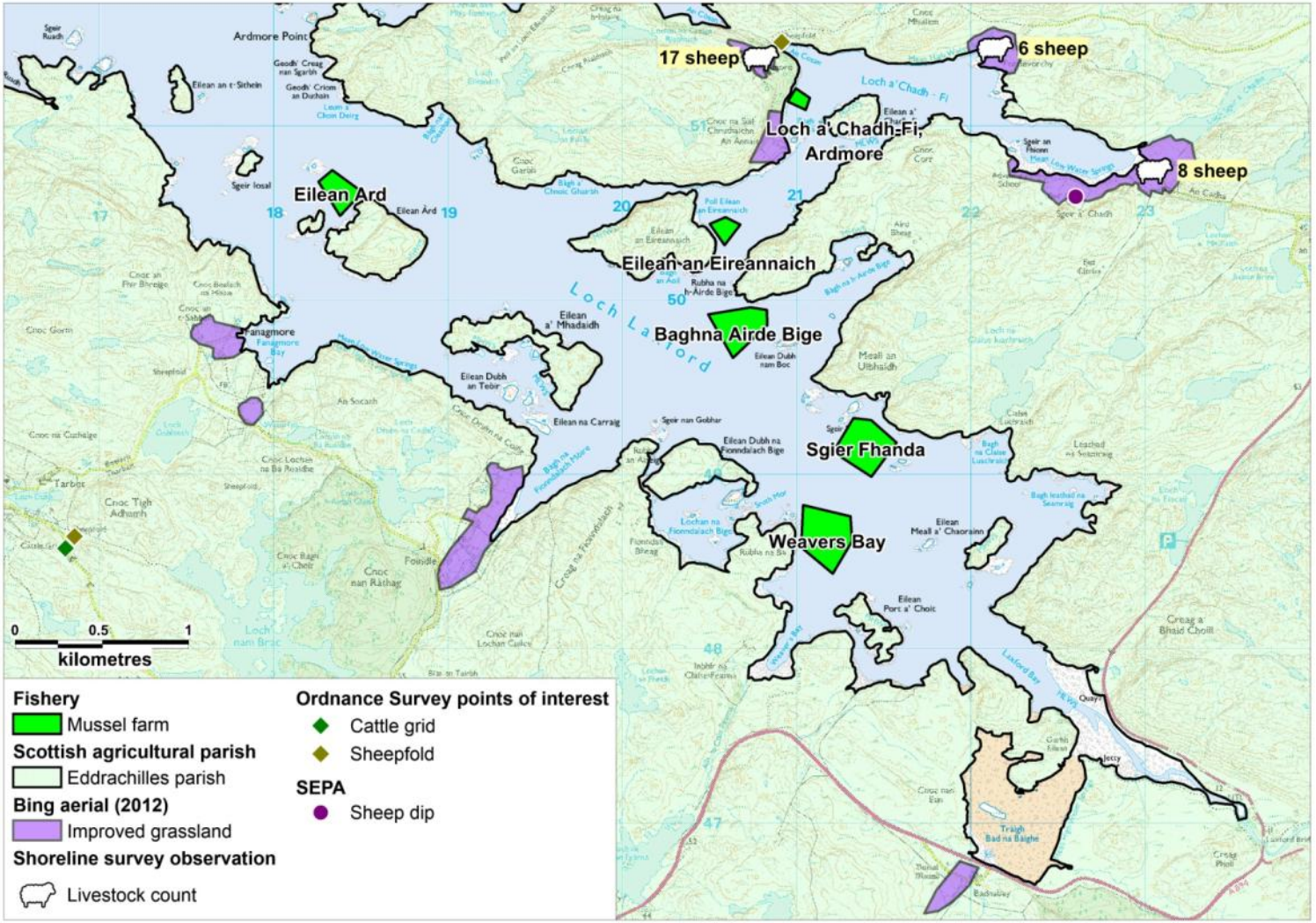

Figure 5.1 Livestock observations at Loch Laxford

6. Wildlife

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

The species most likely to contribute to faecal indicator levels at the Loch Laxford mussel farms are considered below.

Pinnipeds

The Special Committee on Seals reported that between 2007 and 2011 that approximately 50 harbour seals (*Phoca vitulina*) and between 50 and 100 grey seals (*Halichoerus grypus*) were observed at Loch Laxford (SCOS, 2012). There are also anecdotal accounts of seals in Loch Laxford (Ridgeway Adventure, 2011). No seals were observed during the shoreline survey.

Cetaceans

The Hebridean Whale and Dolphin Trust have a sighting reported of a harbour porpoise in Loch Laxford in May 2011 (Hebridean Whale and Dolphin Trust, 2014). No other observations were reported and no cetaceans were noted during the shoreline survey.

Birds

Seabird data was downloaded from the collated JNCC dataset from the website (JNCC, 2014) in March 2014. The most recent data was extracted for locations where more than one count was available. It should be appreciated that the sources of this data are varied, with some recorded, some estimated, and some 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 Loch Laxford are listed in Table 6.1.

Table 6.1 Seabird counts within 5 km of Loch Laxford

Common name	Species name	Count	Qualifier	Accuracy
Fulmar	*Fulmarus glacialis*	504	Occupied sites	One count estimated, remaining accurate
Herring Gull	*Larus argentatus*	100	Occupied nests	One count estimated, remaining accurate
Great Black-Backed Gull	*Larus marinus*	196	Occupied nests	One count estimated, remaining accurate
Shag	*Phalacrocorax aristotelis*	104	Occupied nests	One count estimated, remaining accurate
Common Tern	*Sterna hirundo*	26	Occupied nests	Accurate
Great Cormorant	*Phalacrocorax carbo*	82	Occupied nests	Accurate
Lesser Black-Backed Gull	*Larus fuscus*	4	Occupied nests	Accurate
Common Gull	*Larus canus*	22	Occupied nests	Accurate
Black Guillemot	*Cepphus grylle*	8	Individuals on land	Accurate

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

Significant numbers of cormorants and fulmars were noted on several small islands located 3 km northwest of the Eilean Ard fishery. Other significant numbers of birds were noted where the loch meets the Atlantic ocean where the majority of bird sightings were also made. Approximately 2 km northwest of the Eilean Ard, large numbers of occupied fulmar sites were noted, whilst 1 km northwest of Eilean Ard, significant nesting colonies of great black-backed gulls and shags were noted. At Skerricha, approximately 2 km east of Loch A'Chad-Fi fishery a moderately sized nesting colony of herring gulls and great black-backed gulls were noted.

Handa Island is located just over 5 km southwest of Loch Laxford and is a designated special protected area (SPA) and a site of special scientific interest (SSSI), with internationally important aggregations of breeding birds: fulmar, great skua, guillemot, kittiwake and razorbill (JNCC, 2001). Handa Island regularly supports over 200,000 birds during the breeding season.

Birds were the only wildlife observed during the shoreline survey. In particular, large numbers of greylag geese were seen, with >70 geese including 11 goslings observed near the Loch a' Chadh-Fi and Eilean an Eireanniach mussel farms. According to the RSPB website, greylag geese are resident in the northwest coast of Scotland (RSPB, 2014).This gives the potential for year-round contamination impacts at these fisheries. Other species observed during the shoreline survey included common gulls, great black-backed gulls, cormorants, oystercatchers, black guillemots and eider ducks, though none was present in such high numbers as

greylag geese. Most bird sightings during the shoreline survey were associated with the fisheries, though greylag geese were noted either on land or in the air.

Otters

The Scottish Otter Survey database lists a small number of reports of European otter (*Lutra lutra*) sightings around Loch Laxford (JNCC, 2004). However, these observations relate to the period 1978 to 1991 and thus do not reflect the present otter population around Loch Laxford. However, otters are known to be still present in the Caithness and Sutherland counties (Scottish Natural Heritage, 2013), with the Foinaven SPA located 10 km inland from Loch Laxford noting otters as one of its qualifying features. No otters were observed during the shoreline survey.

Deer

The Highland Biological Recording Group vertebrate survey recorded only three sightings of red deer in the area around Loch Laxford between 1999 and 2006 (JNCC, 2014). However, red deer are known to be prevalent on moorland and roe and sika deer are common within woodland in the Caithness and Sutherland counties (Scottish Natural Heritage, 2013). No deer were observed during the shoreline survey.

Overall

The most significant contamination impact from wildlife is expected to come from birds, owing to the relatively large numbers of birds noted during the shoreline survey, and the high numbers noted to nest/occupy the land around Loch Laxford. In particular, Greylag geese were present in high numbers, and their resident nature suggests they would be a significant contributor to contamination levels within the area, particularly from shorelines where they rest/feed and rear their young. There is likely to be an impact all all of the mussel sites but those towards the head of the loch may be affected less than the others. Although there are resident species in the area, implying a year-round impact, other species will be seasonal and will have a grater impact during the spring and summer. Other species that may contribute to backgrounds levels of contamination include seals, deer and otters, though these remain largely uncertain owing to little available information being available on the populations around Loch Laxford.

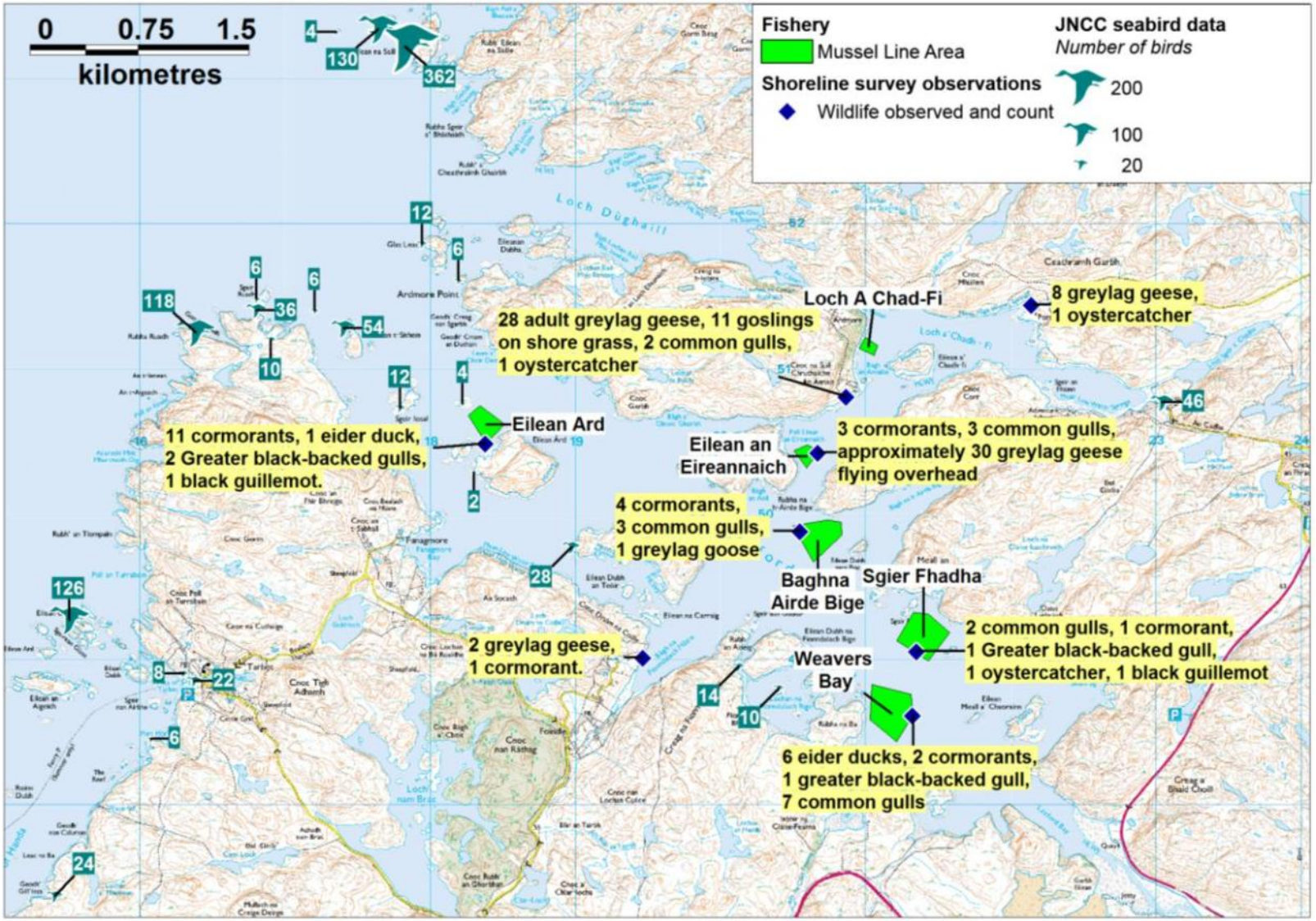

Figure 6.1 Map of wildlife around Loch Laxford

7. Land Cover

The predominant land cover type adjacent to Loch Laxford is dwarf shrub heath. There are also areas of rough grassland, coniferous and broad leaved woodland and improved grassland and scattered small areas of bog and acid grassland. The majority of the shoreline adjacent to the fisheries is composed of dwarf shrub heath and rough grassland. Improved grassland is present on the shorelines south of Loch a' Chadh-Fi, Ardmore and south west of Baghna Airde Bige and Eilean Aird. Broad–leaved woodland is shown in the vicinity of Ardmore. A small area is shown as built up at Ardmore Point at the northwest end of Loch Laxford, this is not shown on the OS map or aerial imagery and is therefore thought to be an error. The Land Cover Map 2007 data for the area is shown in Figure 7.1.

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

The highest potential contribution of contaminated run-off to the Loch Laxford mussel farms are from the areas of improved grassland located nearest to the sites, particularly within Loch a' Chadh-Fi, where the improved grassland area is close to the mussel farm. This contribution would be expected to increase after rainfall events.

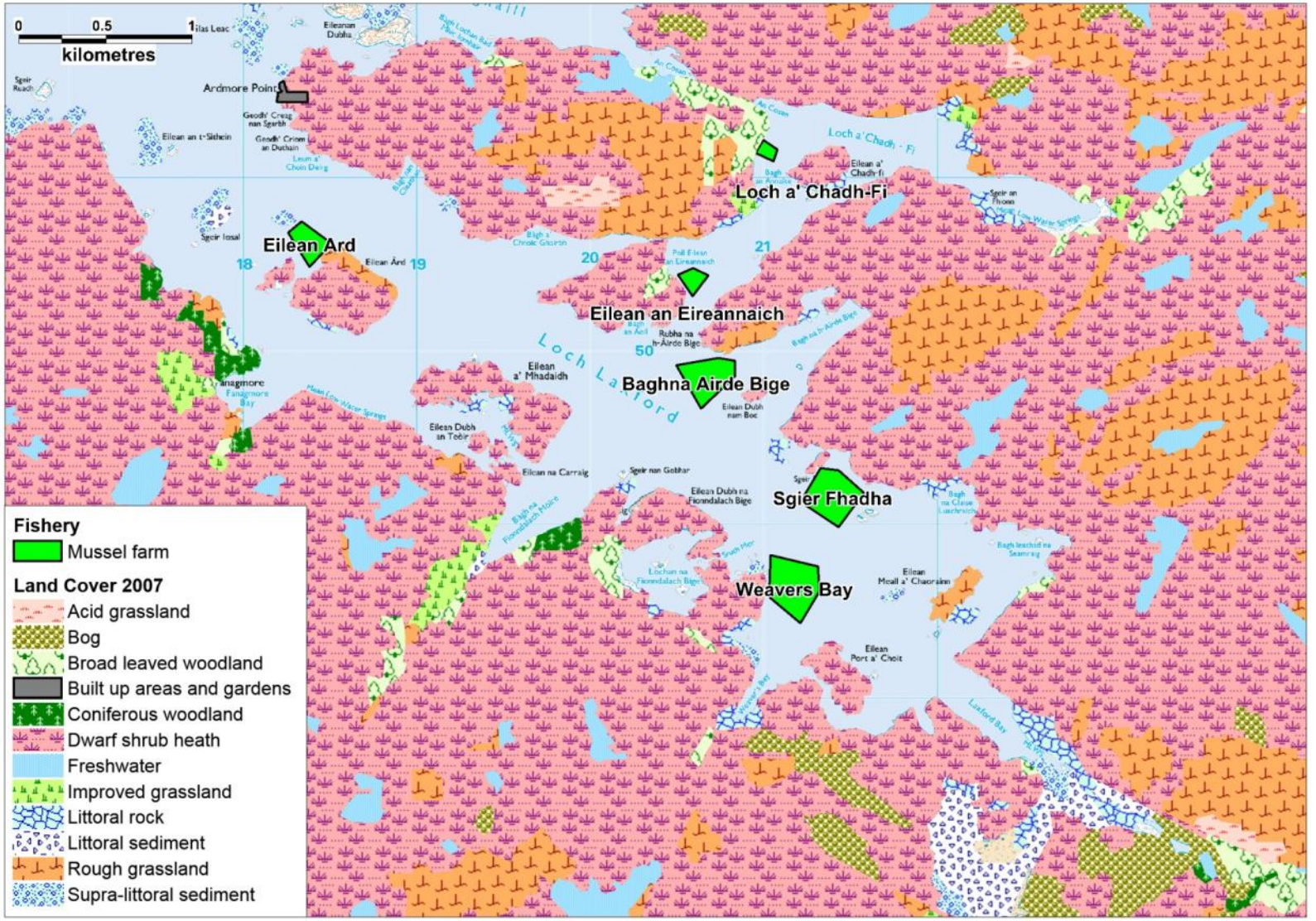

Figure 7.1 LCM2007 land cover data for the area around Loch Laxford

8. Watercourses

There are no gauging stations on watercourses entering Loch Laxford. The largest watercourse discharging to Loch Laxford is the River Laxford, which discharges to the head of the loch.

Spot measurements of flow and microbial content were obtained during the shoreline survey conducted on the 12th and 14th June 2014. Scattered showers were recorded in the 48 hrs prior to the survey. The watercourses listed in Table 8.1 are those recorded during the shoreline survey. One area of land drainage and five small watercourses were observed that were not measured or sampled. Locations of all observed watercourses are mapped in Figure 8.1, with loadings given for measured watercourses.

Table 8.1 Watercourses entering Loch Laxford

No.	Eastings	Northings	Description	Width (m)	Depth (m)	Flow (m^3/d)	Loading (*E. coli* per day)
1	221417	951501	Alltan Mór	0.82	0.07*	2780**	$<2.8 \times 10^8$
2	217784	949822	Unnamed watercourse	Measured volume over time		43	$<4.3 \times 10^6$
3	217772	949790	Unnamed watercourse	Measured volume over time		101	6.1×10^7
4	217813	949719	Tributary of Loch Gobhloch	0.8	0.04	871*	$< 8.7 \times 10^7$
5	219402	948914	Unnamed watercourse	Measured volume over time		11	$<1.1 \times 10^6$
6	219256	948622	Unnamed watercourse	1.8	0.07	3470*	3.5×10^8
7	220726	947827	Allt na Clais Fearna	0.77	0.275	9220*	$< 8.4 \times 10^8$
8	222059	946781	Allt a' Ghleannain & Allt Badna Baighe	3.65	0.06*	7860*	2.8×10^{10}
9	223693	946855	River Laxford	5.2	0.4	119000*	$< 1.2 \times 10^{10}$

* Average taken from multiple measurements **Total over three separate measurements

Only three watercourses (numbers 3, 6 and 8) yielded *E. coli* results greater than the limit of detection and thus allowed estimation of actual loadings. Of these, watercourse 3, discharging into Fanagmore Bay (southwest of the Eilean Ard site) had a low estimated loading. Two of the other watercourses (No. 2 and No. 4) for which only upper limits for the estimated loadings could be made also discharged into that bay. However, the combined loading from all three would be expected to be moderate. Watercourse 6, discharging into Bàgh na Fionndalach Mòire southwest of the Baghna Airde Bige site, had a moderate loading. One of the other watercourses (No. 5) for which only upper limits for the estimated loadings could be made also discharged into that bay. Watercourse 8 had a high loading compared to the other

watercourses. This discharges into Tràigh Bad na Bàighe near the head of the loch. The River Laxford discharges at the head of the loch: on the day of the shoreline survey the *E. coli* concentration of the sample taken from the river was below the limit of detection. However, the high flow of the river means that if the *E. coli* concentration does reach detectable levels on occasions, the resulting loading would be high. Other watercourses for which only upper limits for the estimated loadings could be made were No. 1, Alltan Mòr, situated in Loch a' Chadh-Fi (there were four additional watercourses in that area that were deemed to be too small to record and sample) and No. 7, Allt na Clais Fearna, discharging into Weavers Bay. Overall, freshwater inputs are expected to provide low to moderate levels of contamination to the mussel farms in Loch Laxford, with the highest impact expected from the watercourses that discharge at the head of the loch, affecting the Weavers Bay and Sgier Fhanda sites.

After heavy rainfall, loadings would be expected to be greater and impacts may then also be seen at the Loch a' Chadh-Fi site and the Eilean Ard site, from watercourses located near to those fisheries.

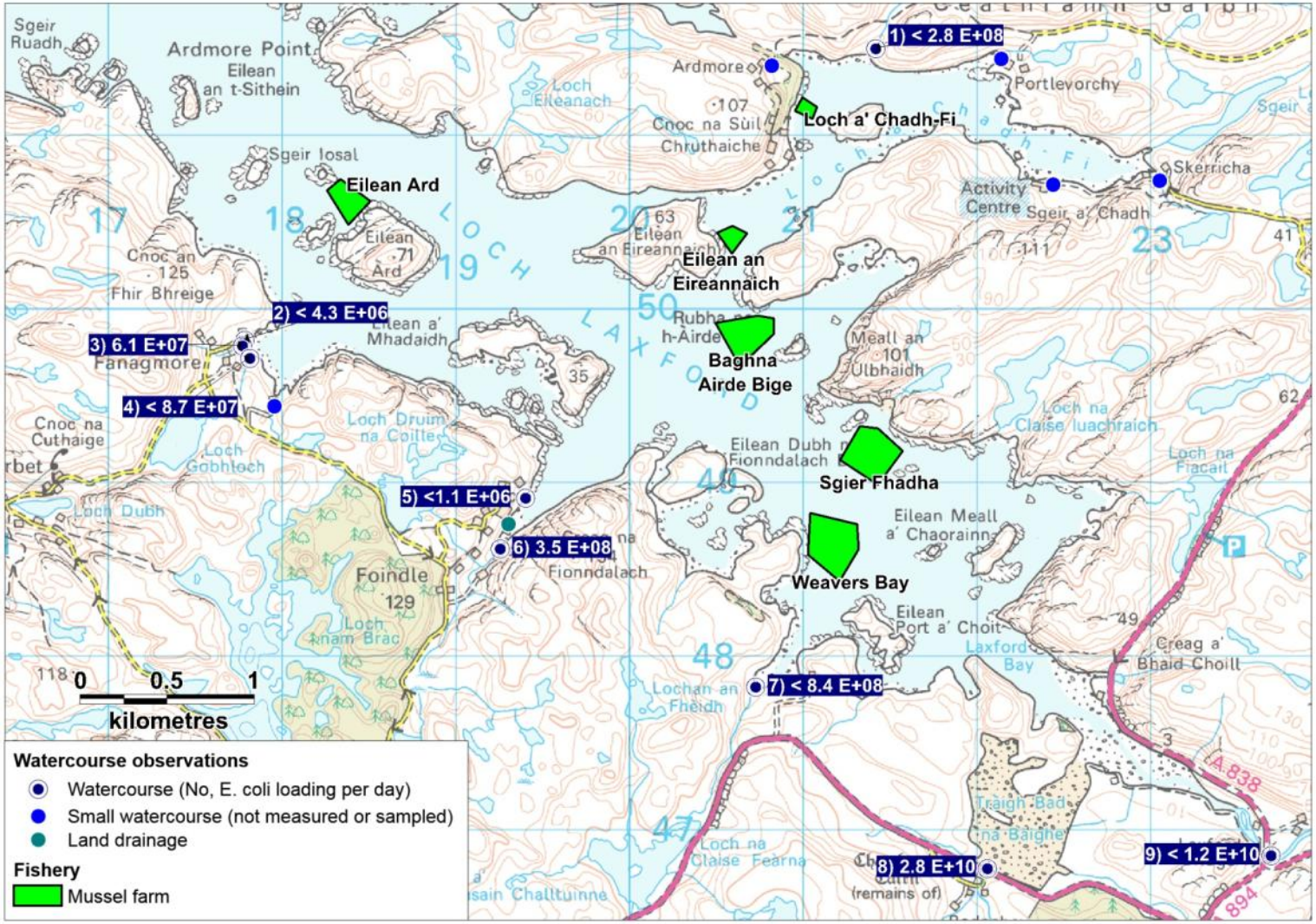

Figure 8.1 Map of watercourse loadings at Loch Laxford

9. Meteorological Data

The nearest weather station for which a complete rainfall data set was available is located at Achfary, situated approximately 12 km to the south east of the production area. Rainfall data was available for January 2008 – December 2013. The nearest wind station is situated in Stornoway Airport, located 76 km west of the production area. Conditions may differ between this station and the fisheries due to the distances between them. However, this data is still shown as it can be useful in identifying seasonal variation in wind patterns.

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

9.1 Rainfall

High rainfall and storm events are commonly associated with increased faecal contamination of coastal waters through surface water run-off from land where livestock or other animals are present, and through sewer and waste water treatment plant overflows (Mallin, et al., 2001; Lee & Morgan, 2003). The box and whisker plots in Figures 9.1 and 9.2, present a summary of the distribution of individual daily rainfall values by year and by month. The grey box represents the middle 50% of the observations, with the median at the midline. The whiskers extend to the largest or smallest observations up to 1.5 times the box height above or below the box. Individual observations falling outside the box and whiskers are represented by the symbol *.

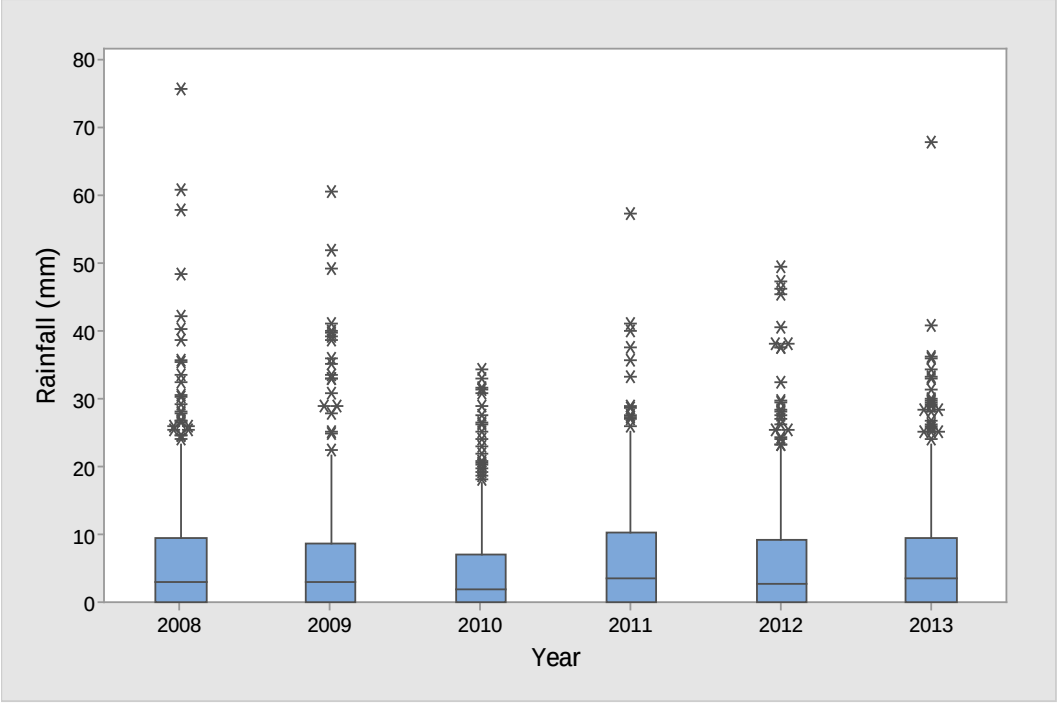

Figure 9.1 Box plot of daily rainfall values by year at Achfary (2008 – 2013)

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

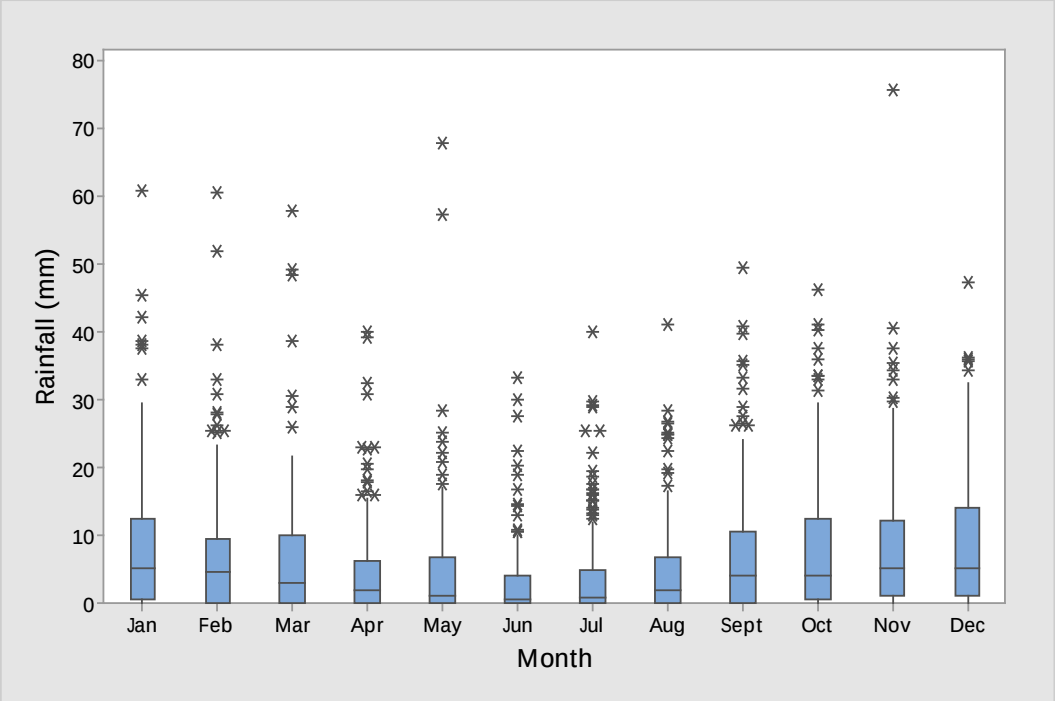

Figure 9.2 Box plot of daily rainfall values by month at Achfary (2008 – 2013)

Total monthly rainfall values were higher during the autumn and winter. Rainfall was greatest in October (1348 mm) and least in June (429 mm). Rainfall values exceeding 40 mm/d occurred in all months bar April, June and July while high rainfall values of 60 mm/d were seen in January, February, May and November.

For the period considered here (2008 – 2013), 38 % of days received daily rainfall of less than 1 mm and 22 % of days received daily rainfall of over 10 mm.

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

9.2 Wind

Wind data was collected from Stornoway Airport and summarised in seasonal wind roses in Figure 9.3 and an annual wind rose in Figure 9.4.

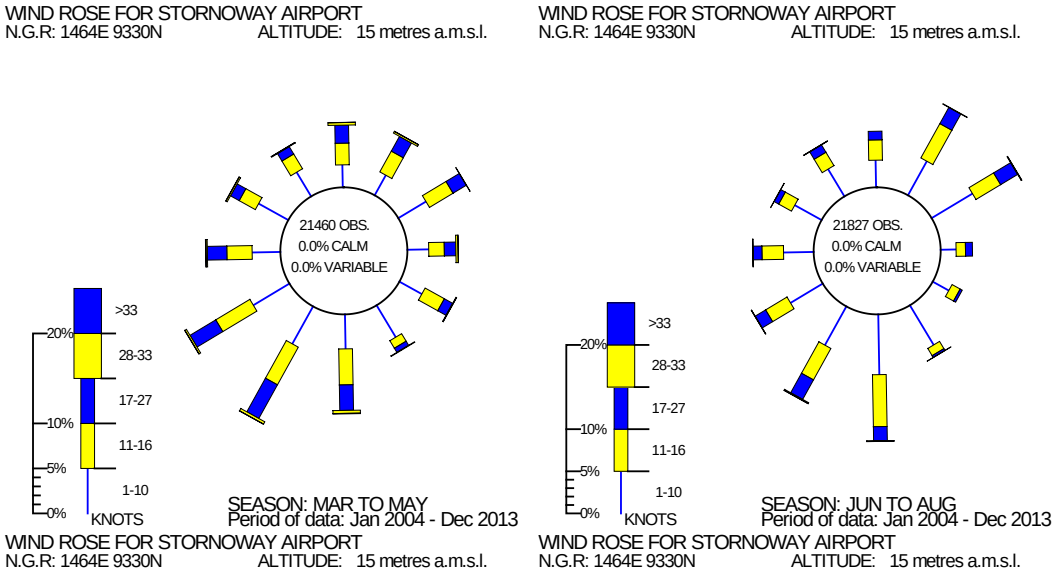

Figure 9.3 Seasonal wind roses for Stornoway Airport

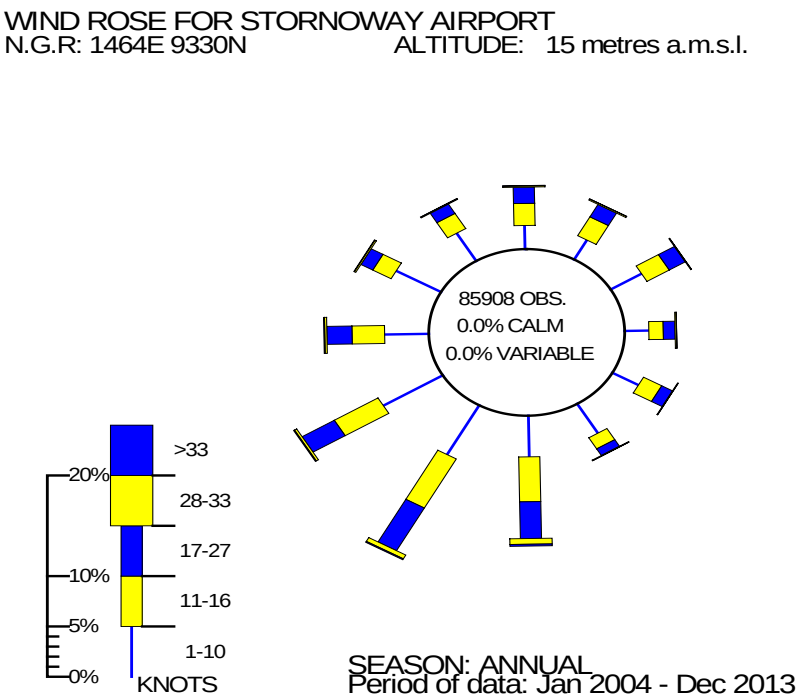

Figure 9.4 Annual wind rose for Stornoway Airport

Overall the winds predominantly came from the southwest. The strongest winds also tended to come to from this quarter. Seasonally the strongest winds occurred during the winter. Typically the wind came from around the southwest through most of the year but the summer also saw winds coming from the south and northeast. As Loch Laxford opens to the northwest, winds coming from a westerly direction are likely to be funnelled up the main body of the loch.

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

Table 10.1 Loch Laxford: (common mussel) classification history

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2006	A	A	A	A	A	A	A	A	A	A	A	A
2007	A	A	A	A	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									

The production area has been consistently given a year-round A classification.

11. Historical *E. coli* Data

11.1 Validation of historical data

Results for all samples assigned against Loch Laxford production area for the period 01/01/2009 to the 17/06/2014 were extracted from the FSAS database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. The data was extracted from the database on 17/06/2014. All *E. coli* results were reported as most probable number (MPN) per 100 g of shellfish flesh and intravalvular fluid.

Over half the samples had results reported as <20 (or <18) and these were reassigned a value of 10 *E. coli* MPN/100 g for the purposes of statistical evaluation and graphical representation.

Three samples were recorded as rejected and were omitted from further analysis in this report. A fourth sample did not have a reported result and was therefore also omitted from further analysis. The remaining 60 samples were all received within 48 hours of collection, had box temperatures of <8^{o}C and plotted within the production area boundaries.

11.2 Summary of microbiological results

Table 11.1 Summary of historical sampling and results

Sampling Summary	
Production area	Loch Laxford
Site	Weavers Bay
Species	Common mussels
SIN	HS-167-320-08
Location	Various
Total no of samples	60
No. 2009	11
No. 2010	12
No. 2011	9
No. 2012	11
No. 2013	12
No. 2014	5
Results Summary	
Minimum	<18
Maximum	790
Median	<20
Geometric mean	<20
90 percentile	130
95 percentile	325
No. exceeding 230/100g	3 (5%)
No. exceeding 1000/100g	0
No. exceeding 4600/100g	0
No. exceeding 18000/100g	0

Sampling has been relatively even across years. The majority of samples taken at Weavers Bay have had low results, with only three sample results >230 *E. coli* MPN/100 g. No sample yielded a result >1000 *E.* coli MPN/100 g.

11.3 Overall geographical pattern of results

The geographical locations of all sample results assigned to Loch Laxford are mapped thematically in Figure 11.1. Two samples had unverified sampling locations and have therefore not been included in this geographical analysis. An obviously incorrect grid reference given for a third sample was amended in order to allow the location to be mapped.

The majority of samples (n=41) were recorded as having been taken at the RMP located at NC 2134 4858. The majority of samples with results >230 *E. coli* MPN/100 g were reported against this location including the maximum result of 790 *E. coli* MPN/100 g. Other reported sample locations were at the northwestern end of the Weavers Bay site, within Weavers Bay itself, and at the Sgeir Fhadha site.

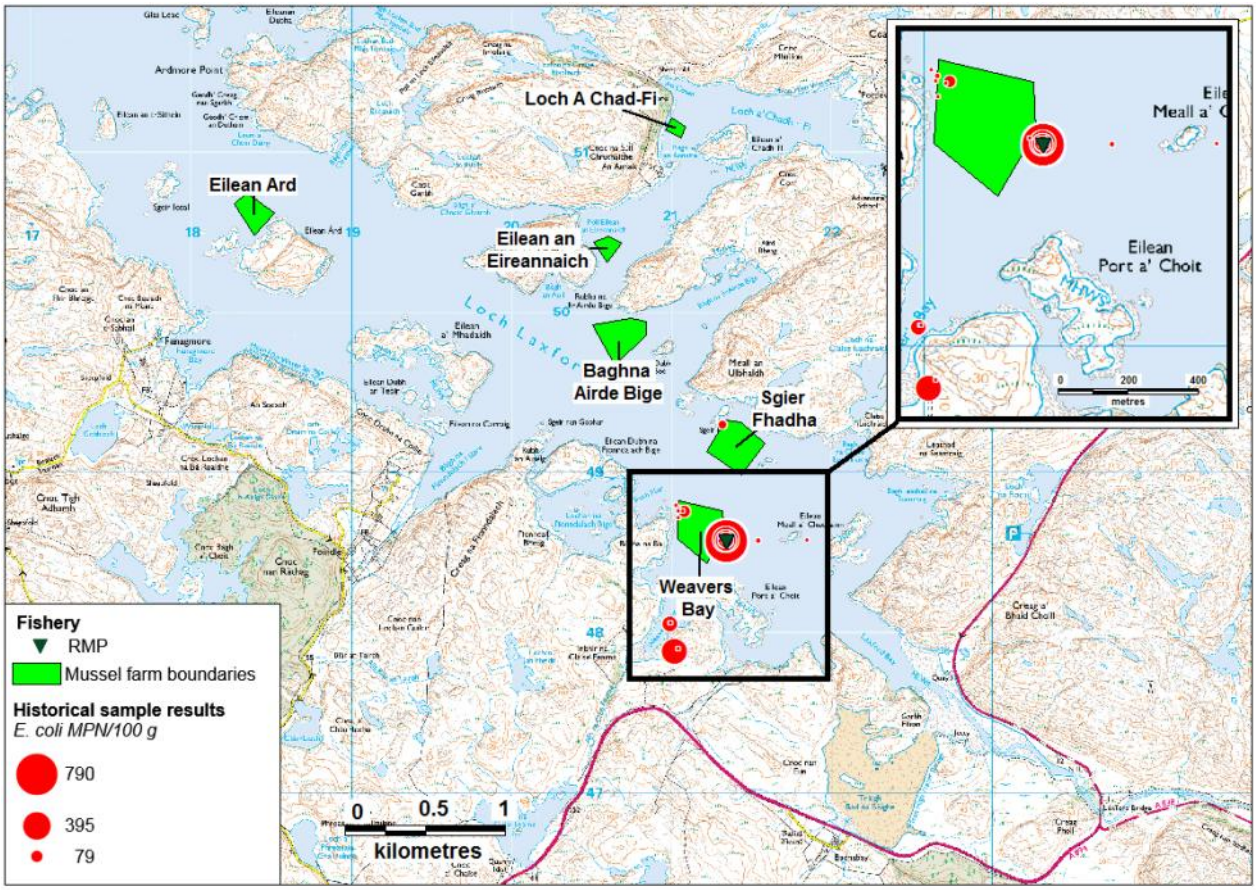

Figure 11.1 Map of reported sampling locations for common mussels at Loch Laxford

11.4 Overall temporal pattern of results

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

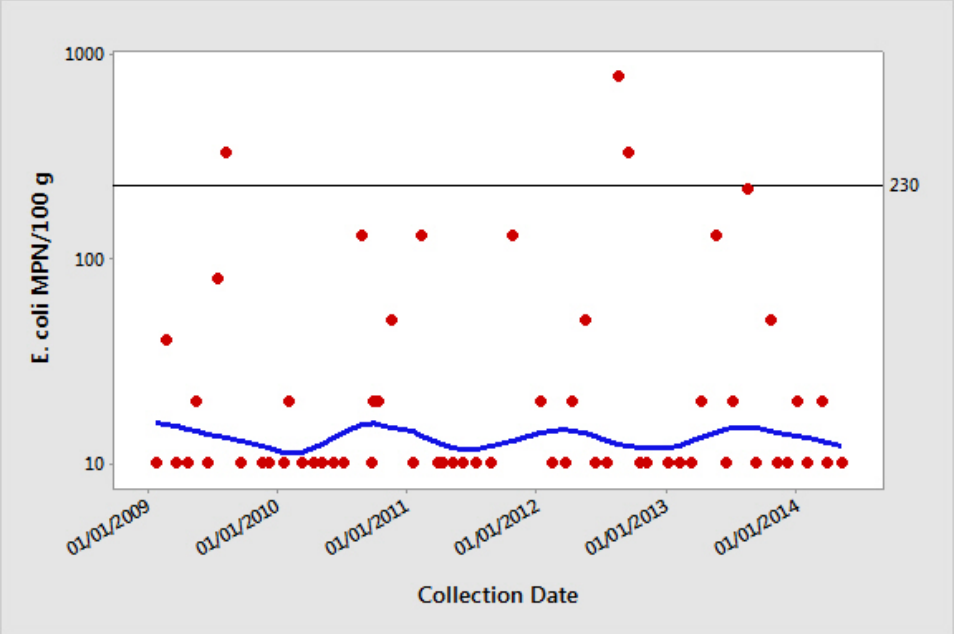

Figure 11.2 Scatterplot of *E. coli* results by collection date at Loch Laxford, fitted with a lowess line

Contamination levels have been low overall and the underlying extent of contamination has not changed markedly over the assessment period. The lowess line shows small periodic changes with peaks occurring during the latter half of years 2010 and 2013, but in the first half of 2012. These peaks are therefore not consistently associated with season.

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. A scatterplot of *E. coli* results by month, overlaid by a lowess line to highlight trends for Loch Laxford is displayed in Figure 11.3. Jittering was applied to the symbols at 0.02 (x-axis) and 0.001 (y-axis) respectively.

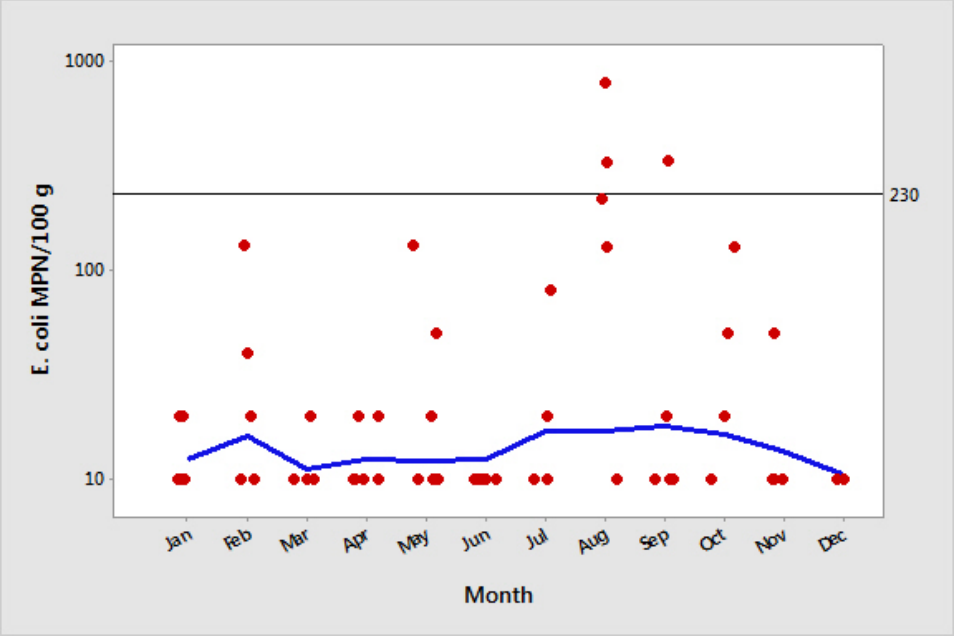

Figure 11.3 Scatterplot of *E. coli* results by month at Loch Laxford, fitted with a lowess line

The highest contamination levels have occurred in August and September. Sampling was not even between months, and varied between 2 (December) and 6 (May).

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

No significant differences were found between mean $\log_{10}$-transformed *E. coli* results for Loch Laxford by season (one-way ANOVA, p = 0.240) (Appendix 4).

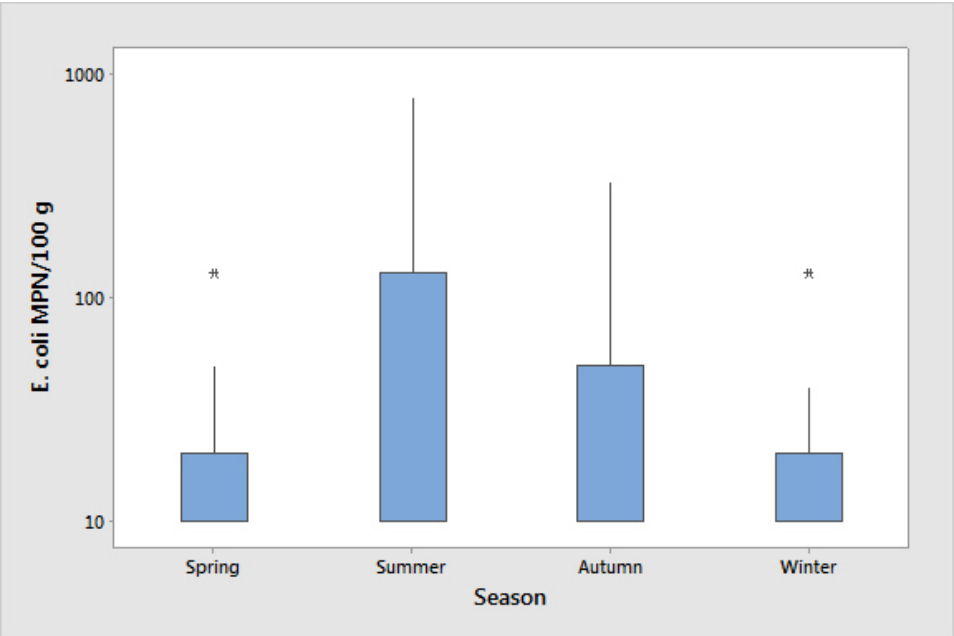

Figure 11.4 Boxplot of *E. coli* results by season at Loch Laxford

11.5.1 Analysis of results against environmental factors

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

11.5.2 Analysis of results by recent rainfall

The nearest weather station with available rainfall data was at Achfary approximately 12 km southeast of Loch Laxford. Rainfall data was purchased from the Meteorological Office for the period of 01/01/2009 - 31/12/2013 (total daily rainfall in mm).

Two-day rainfall

A scatterplot of *E. coli* results against total rainfall recorded on the two days prior to sampling for Loch Laxford is displayed in Figure 11.5. Rainfall data was available for 51 out of 60 sampling occasions. Jittering was applied to symbols at 0.02 (x-axis) and 0.001 (y-axis) respectively.

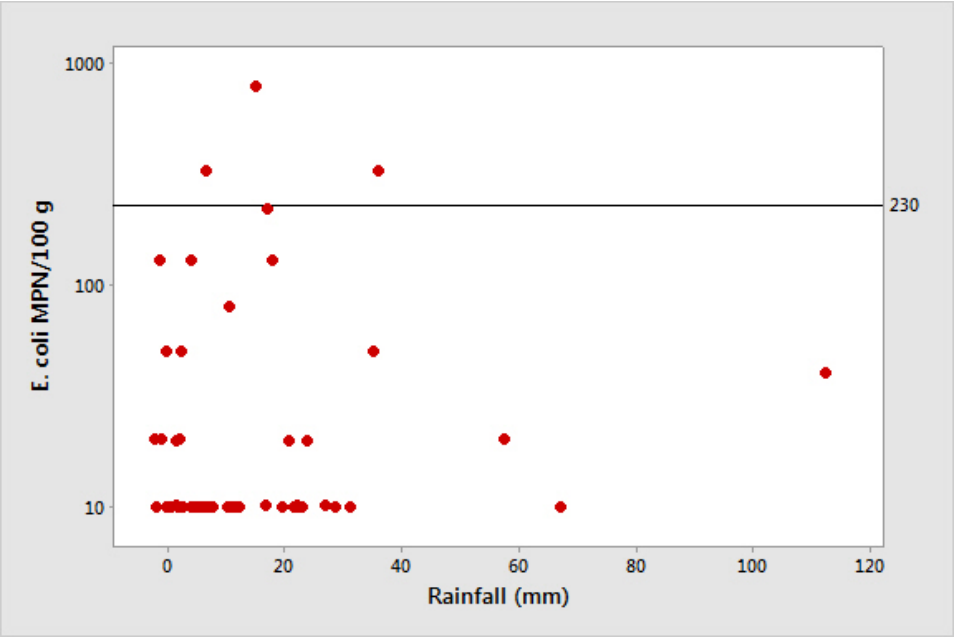

Figure 11.5 Scatterplot of *E. coli* results against rainfall in the previous two days at Loch Laxford

No statistically significant correlation was found between *E. coli* results and the previous two day rainfall (Spearman's rank correlation r = 0.058, p = 0.688).

Seven-day rainfall

The effects of heavy rainfall may take differing amounts of time to be reflected in shellfish sample results in different system, the relationship between rainfall in the previous seven days and sample results was investigated in an identical manner to the above. A scatterplot of *E. coli* results against total rainfall recorded for the seven days prior to sampling at Loch Laxford is shown in Figure 11.6. Rainfall data was available for 48 out of 60 sampling occasions. Jittering was applied to symbols at 0.02 (x-axis) and 0.001 (y-axis) respectively.

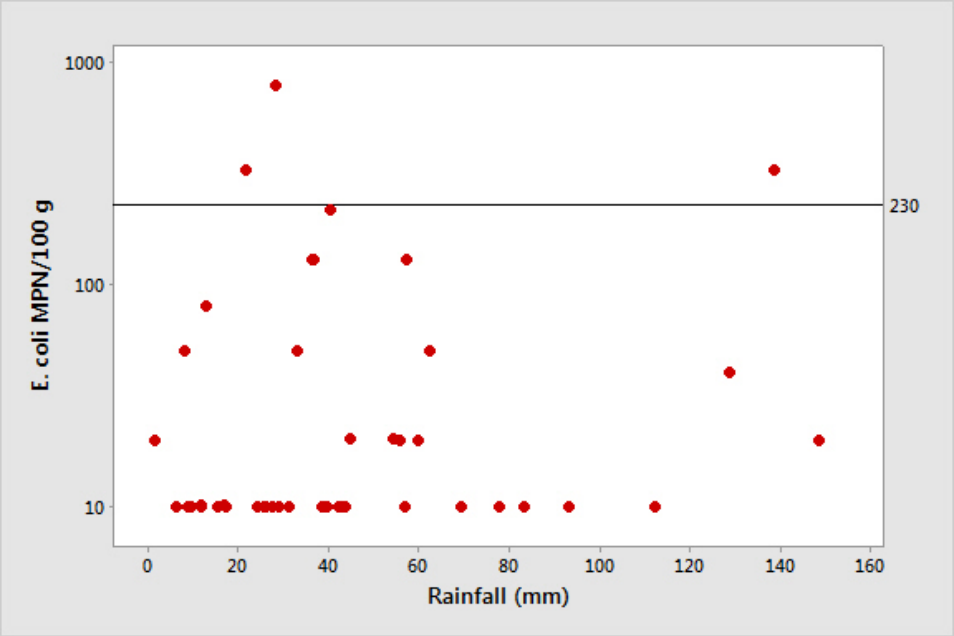

Figure 11.6 Scatterplot of *E. coli* results against rainfall in the previous seven days at Loch Laxford

No statistically significant correlation was found between *E. coli* results and the previous seven day rainfall (Spearman's rank correlation r = 0.160, p = 0.277).

11.5.3 Analysis of results by tidal height

Spring/neap tidal cycle

Spring tides are large tides that occur fortnightly and are influenced by the state of the lunar cycle. They reach above the mean high water mark and therefore increase circulation and particle transport distances from potential contamination sources on the shoreline. The largest (spring) tides occur approximately two days after the full/new moon, at about 45^{o} on a polar plot. The tides then decrease to the smallest (neap) tides, at about 225^{o}, before increasing back to spring tides. A polar plot of *E. coli* results against the lunar cycle is shown for Loch Laxford in Figure 11.6**.** It should be noted local meteorological conditions (e.g. wind strength and direction) can also influence tide height, but is not taken into account in this section.

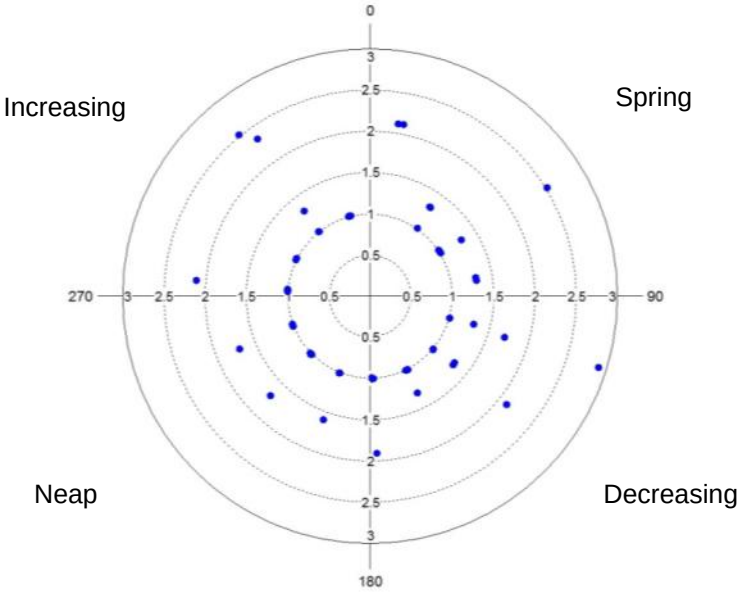

Figure 11.7 Polar plots of log10 E. coli results on the spring/neap tidal cycle at Loch Laxford

A statistically significant correlation was found between $\log_{10}$ *E. coli* results and the spring/neap tidal cycle (circular-linear correlation r = 0.245, p = 0.033). Higher results occurred in samples taken at, and either side of, spring tides.

High/low tidal cycle

Tidal state (high/low tide) changes the direction and strength of water flow around production areas. Depending on the location of contamination sources, tidal state may cause marked changes in water quality near the vicinity of the farms. Shellfish species response time to *E. coli* levels can vary from within an hour to a few hours. A polar plot of *E. coli* results against the high/low tidal cycle for Loch Laxford is shown in Figure 11.7. High water is located at 0^o on the polar plot and low water at 180^o.

High and low water data for Loch Laxford was extracted from POLTIPS-3 in June 2014.

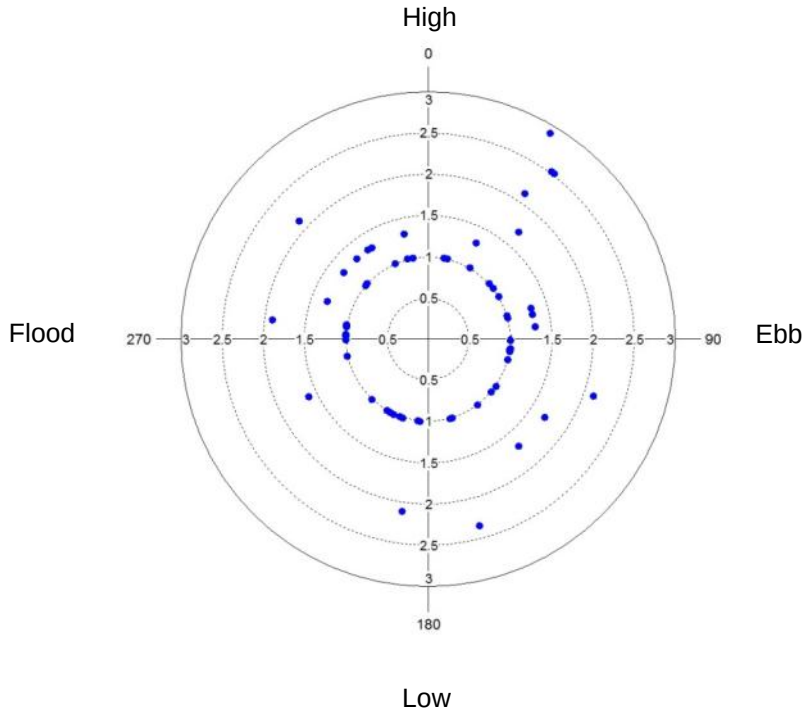

Figure 11.8 Polar plots of log_{10} *E. coli* results on the high/low tidal cycle at Loch Laxford

No statistically significant correlation was found between log_{10} *E. coli* results and the high/low tidal cycle (circular-linear correlation r = 0.196, p = 0.112) although the highest results were obtained from samples taken shortly after high tide.

11.5.4 Analysis of results by water temperature

Water temperature can affect survival time of bacteria in seawater (Burkhardt, *et al*., 2000). It can also affect the feeding and elimination rates in shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. Water temperature is obviously closely related to season. Any correlation between temperatures and *E. coli* levels in shellfish flesh may therefore not be directly attributable to temperature, but to the other factors e.g. seasonal differences in livestock grazing patterns. A scatterplot of *E. coli* results against water temperature for Loch Laxford is shown in Figure 11.9. Water temperature was recorded for 36 out of 60 Loch Laxford samples and jittering of symbols was applied at 0.02 (x-axis) and 0.001 (y-axis) respectively.

No statistically significant correlation was found between *E. coli* results and water temperature (Spearman's rank correlation r = 0.179, p = 0.296) although the highest results were from samples taken at temperatures >9^{o}C.

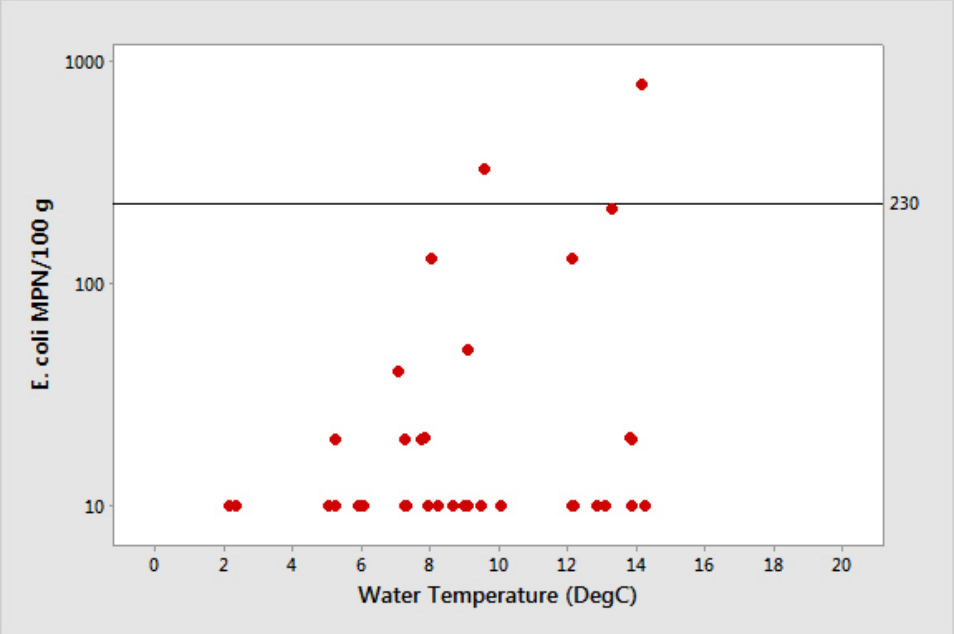

Figure 11.9 Scatterplot of *E. coli* results against water temperature at Loch Laxford

11.5.5 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence and hence freshwater borne contamination at a site. A scatterplot of *E. coli* results against salinity for Loch Laxford is shown in Figure 11.10. Salinity was recorded for 30 out of 60 of the Loch Laxford samples and jittering of symbols was applied at 0.02 (x-axis) and 0.001 (y-axis) respectively.

No statistically significant correlation was found between common mussel *E. coli* results and salinity (Spearman's rank correlation r = -0.018, p = 0.926). The majority of samples were taken at salinities >20 ppt.

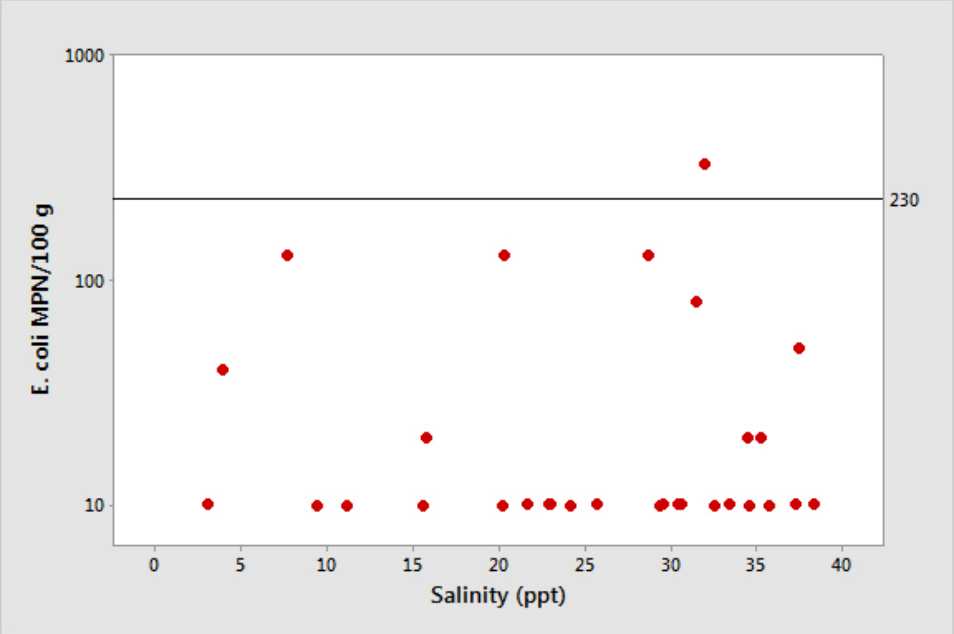

Figure 11.10 Scatterplot of *E. coli* results against salinity at Loch Laxford

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

Three common mussel samples gave results >230 *E. coli* MPN/100 g and are listed below in Table 11.2.

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

Collection Date	*E. coli* (MPN/ 100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (^{o}C)	Salinity (ppt)	Tidal state (spring/neap)	Tidal State (high/ low)
04/08/2009	330	NC 2101 4788	4.5	18.9	-	32	Increasing	High
21/08/2012	790	NC 2134 4858	14.2	26.7	14	-	Decreasing	High
18/09/2012	330	NC 2134 4858	34.5	137.2	9.6	-	Spring	High

-No data available

The samples were taken in August and September, with the highest result of 790 *E. coli* MPN/100 g eing from a sample taken in late August. Two of the samples were taken in 2012..

Rainfall over the two days prior to sampling varied between 4.5 and 34.5 mm, whilst over the previous seven days it varied between 18.9 and 137.2 mm. Water temperature was only recorded for the two 2012 samples and varied between 9.6 and 14^{o}C, whilst salinity was only recorded for the 2009 sample: this was 32 ppt. There did not appear to be a trend in spring/neap tidal states, although all three samples were taken around high tide.

11.7 Summary and conclusions

Regular sampling has been carried out at Loch Laxford over the 2009-2014 sampling period, with the majority of samples indicating low levels of contamination. Two of

the three sample results >230 *E. coli* MPN/100 g were recorded as having been taken at the RMP (NC 2134 4858), including the highest sample of 790 *E. coli* MPN/100 g.

There was no statistical difference in average *E. coli* with season. However, the highest results were from samples taken in August and September. A statistically significant correlation was found between mussel *E. coli* results and the spring/neap tidal cycle, with highest results obtained from samples taken at or around spring tide. No statistically significant correlations were found between the mussel *E. coli* results and any of the other environmental variables that were investigated.

12. Designated Waters Data

Shellfish Water Protected Areas

The Shellfish Waters Directive (2006/113/EC) has been repealed (as at 31 December 2013) and equivalent protection for areas previously designated under that Directive is given by The Water Environment (Shellfish Water Protected Areas: Environmental Objectives etc.) (Scotland) Regulations 2013. The Loch Laxford Shellfish Water Protected Area (SWPA) has the same boundaries as the previous Loch Laxford, North West Shellfish Growing Water (SGW). The SWPA designation has the same boundary as the Loch Laxford production area. There is an historic SGW monitoring point located in Loch Laxford at NC 2260 4770. Since 2007, SEPA has used the FSAS *E. coli* data for assessing microbiological quality. The designated SWPA for Loch Laxford is shown in Figure 12.1.

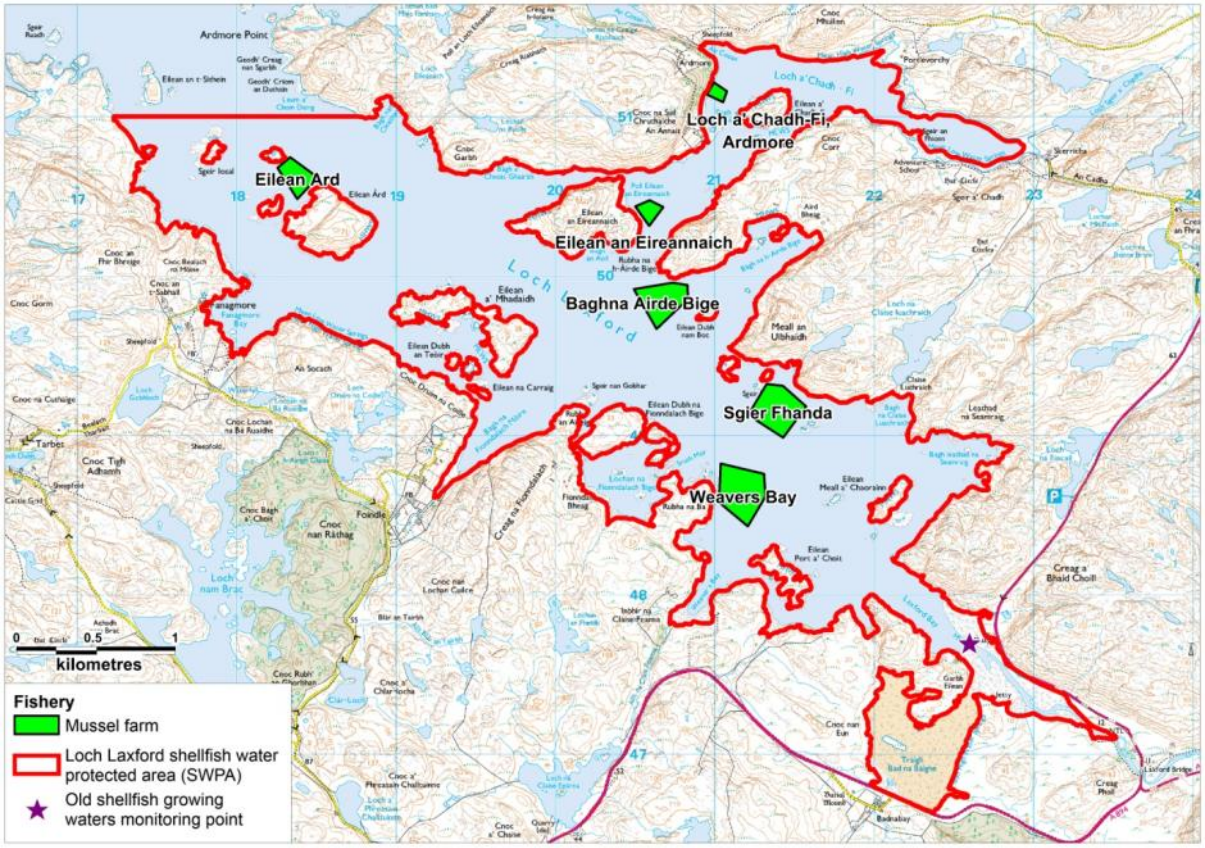

Figure 12.1 Designated shellfish water protected area – Loch Laxford

A site report was prepared for Loch Laxford in 2011 by SEPA under the now repealed Shellfish Waters Directive. This report noted only a small number of septic tank discharges from private dwellings. The compliance history given for faecal coliforms between 2000 and 2010 showed a pass in all but two years.

Bathing Waters

There are no designated bathing waters within Loch Laxford.

13. Bathymetry and Hydrodynamics

13.1 Introduction

13.1.1 The Study Area

Loch Laxford is situated in the Highland district on the northwest coast of Scotland. The landscape around the loch is complex, characterised by low hills and numerous small freshwater lochs. The assessment area lies in a sparsely populated region, away from industrial activities and agriculture. At its mouth, Loch Laxford joins the adjacent Loch Dùghaill towards the north, at Ardmore Point. Loch Laxford is also joined by the subsidiary Loch a' Chadh-Fi further east along its northern shore, with the island Eilean Eireannaich located at their junction. Numerous small streams and burns flow into Loch Laxford from nearby freshwater lochs, including Loch Elleanach, Loch na Claise luachraich, Loch na Fiacail, Loch Druim na Coilte, and Loch Ghobloch. At the south-eastern end of the loch the River Laxford empties into Laxford Bay.

Two small settlements are found along the southern edge of Loch Laxford: Foindle and Fanagmore, both accessible by a minor road.

The assessment area encompasses all of Loch Laxford to the south of Ardmore Point, including Eilean an t-Sithein and the connected subsidiary loch, Loch a' Chadh-Fi. It is shown in Figure 13.1 with the assessment area demarcated by the red line. The total length of Loch Laxford is 7.0 km (Edwards & Sharples, 1986). The shoreline of Loch Laxford is complex and punctuated by bays and inlets, and so the width of the loch is rather poorly defined and probably varies from approximately 0.5 km to 2.0 km.

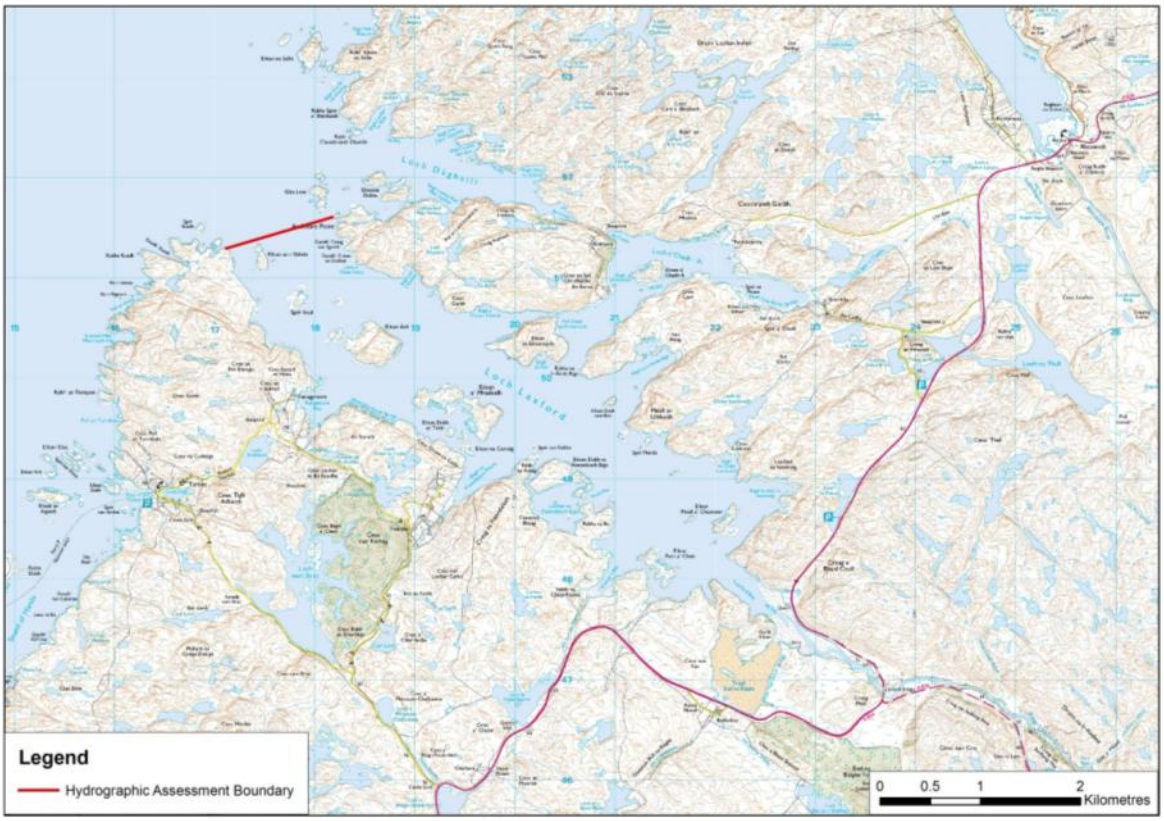

Figure 13.1 Extent of the hydrographic study area

Loch Laxford is also classified as a Special Area of Conservation, or SAC. It is designated as such because of the characteristic fjard (distinct from a fjord) environment and associated large shallow inlets and bays. It contains a multitude of habitats and communities, including notable quality bedrock reef communities (Bates, *et al*., 2004).

Coordinates for Loch Laxford:

58.402222°N 005.084722°W
OS NC 198501

13.2 Bathymetry and Hydrodynamics

13.2.1 Bathymetry

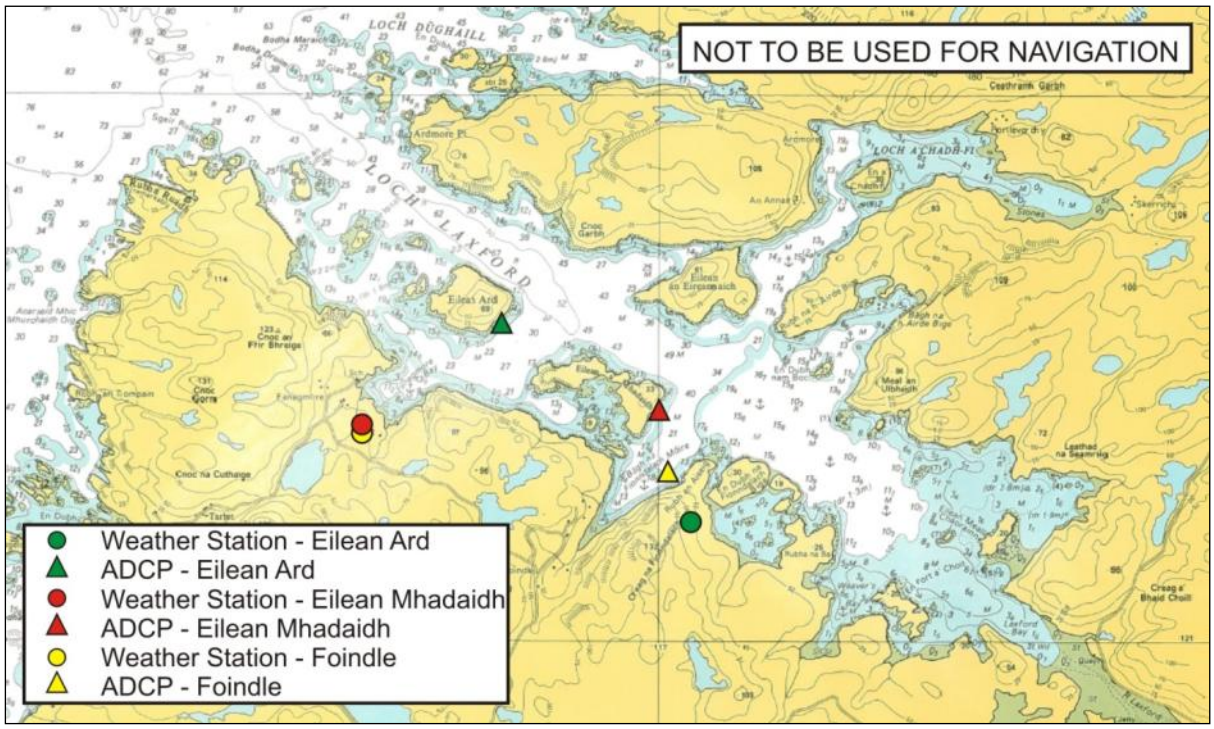

Figure 13.2 Admiralty chart (2503, Edition 3 year 1982) extract for Loch Laxford. Locations of ADCPs and weather stations within assessment area are shown.

Figure 13.2 shows the bathymetry of Loch Laxford. There is one principal sill which is found at the mouth of the loch, extending from approximately 100 m south of Ardmore point across the loch and to the south of the island Eilan an t-Sithein. The sill is 1.04 km in width and has a mean depth of 22 m and a maximum depth of 46 m (Edwards & Sharples, 1986). The basin to the east of this sill, within the main body of the assessment area, has a maximum depth of 67 m. To the west of the sill, bathymetry deepens in an offshore direction to depths of 70 m – 90 m.

The mean depth of the assessment area at low water is 20.6 m, while the estimated low water volume is $1.71 \times 10^8 m^3$ (Edwards & Sharples, 1986).

There is a fairly extensive intertidal embayment at the head of Loch Laxford, Tràigh Bad na Baighne, of approximately 0.5 km^2, extending southeast from Laxford Bay.

13.2.2 Tides

Data on tidal information is provided based on tidal characteristics determined from the site.

Standard tidal data for Loch Laxford, centred around the survey date of 11th May 2014, are shown in Figure 13.3. Tidal predictions for Loch Laxford indicate that in this region the tidal characteristics are semi-diurnal, with a well-developed spring-neap cycle.

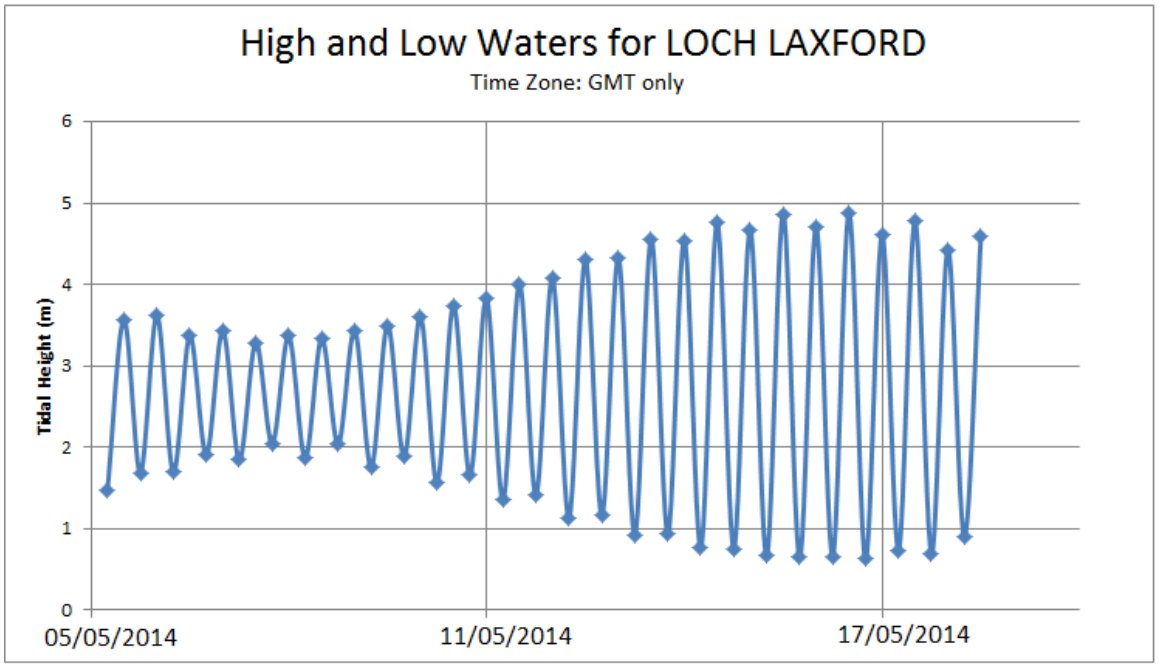

Figure 13.3 Two week tidal curve for Loch Laxford.
Reproduced from Poltips3 [www.pol.ac.uk/appl/poltips3]

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

Mean High Water Springs = 4.9 m
Mean Low Water Springs = 0.7 m
Mean High Water Neaps = 3.5 m
Mean Low Water Neaps = 1.9 m

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

Springs: 3.57×10^7 m^3
Neaps: 1.36×10^7 m^3

13.2.3 Tidal Streams and Currents

There are no published tidal diamonds for this area. Some enhancement of the speed of the tidal streams caused by the many channels between islands and the numerous shallow areas will be important along the length of Loch Laxford.

Current meter data were available at three specified sites within the assessment area: Eilean Ard, Eilean a'Mhadaidh, and Foindle. Data were obtained from SEPA for the three 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: 16th-31st December 2004 at Eilean Ard (Fish Vet Group, 2005), between the 22nd of January and 6th Feburary at Eilean a'Mhadaidh (Fish Vet Group, 2011a), and between the 20th of July and 4th of August, 2011, at Foindle (Fish Vet Group, 2011b).

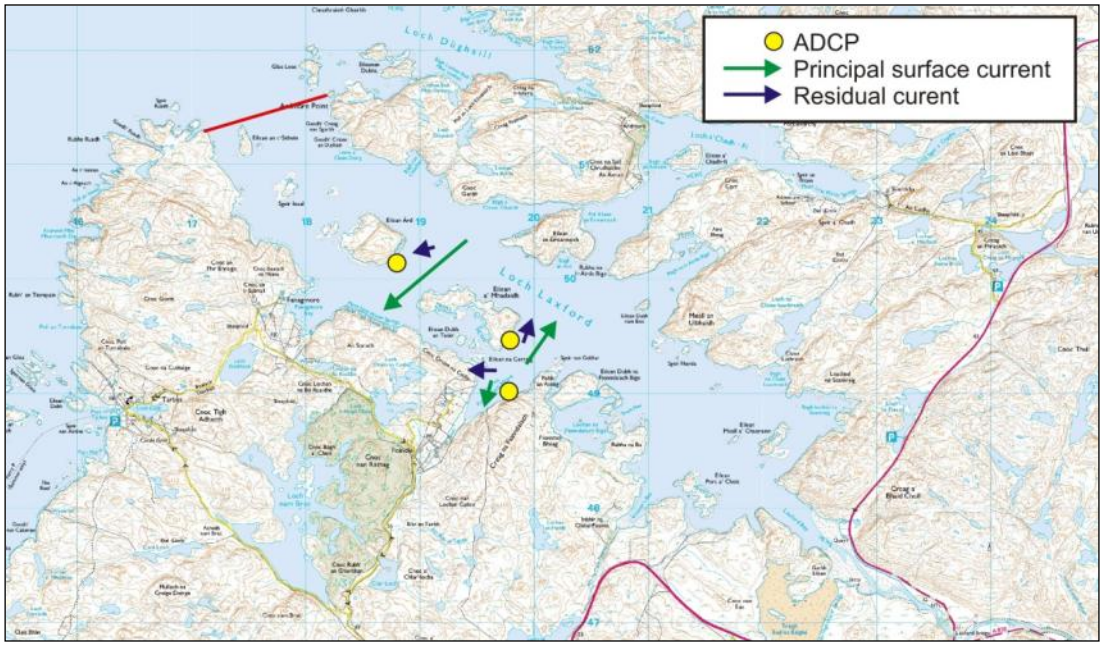

Figure 13.4 Map showing Loch Laxford ADCP sample sites within the assessment area. Using the surface principal current amplitude and residual current velocities and the assumption of a uniform sinusoidal tide, the cumulative transport distance and direction that might be expected during each phase of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

Data from Eilean Ard, N 58°24.118', W 005°06.081' were collected between 16/12/04 and 31/12/04 and are summarised in Table 13.1. The average water depth recorded for the duration of the survey was 29.8 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 this site are most frequently characterised by flows along a south-westerly – north-easterly axis, aligned with the adjacent shoreline. This was also the most frequent current direction, though the strongest currents at the surface

occurred in an east-north-easterly direction, and may have been influenced by prevailing winds. Residual current directions fall within a similar range as principal current directions, and residual current speeds were rather similar across all depths. No distinct pattern was observed in tidal flows across the spring-neap cycle.

Table 13.1 Eilean Ard current data measured in 2004

Average Depth	Near-bed (3.6 m above seabed)	Mid-water (19.6 m above seabed)	Sub-surface (23.6 m from seabed)
Mean Speed (ms^{-1})	0.034	0.037	0.049
Maximum Speed (ms^{-1})	0.275	0.214	0.241
Principal Axis Amp & Dir (ms^{-1}) & (^{o}M)	0.042 (240)	0.049 (240)	0.07 (230)
Residual speed (ms^{-1})	0.011	0.015	0.013
Residual direction (^{o}M)	231	255	236

A weather station was also deployed during the Eilean Ard survey. Wind speeds were on average 8.5 m/s, and reached a maximum of 16.5 m/s. Winds were generally considered to represent a 'moderate to fresh breeze', and most frequently came from a south-westerly or westerly direction – potentially accounting or the strong east-north-easterly currents in the sub-surface waters.

Data were collected from Eilean a'Mhadaidh, N 58°23.846' W 005°04.966, between 22/01/2011 and 06/02/2011 and are summarised in Table 13.2. The average water depth recorded during the survey was 28.4 m.

Table 13.2 Eilean a'Mhadaidh current data measured in 2011

Average Depth	Near-bed (2.7 m above seabed)	Mid-water (17.7 m above seabed)	Sub-surface (20.7 m from seabed)
Mean Speed (ms^{-1})	0.031	0.033	0.025
Maximum Speed (ms^{-1})	0.139	0.125	0.167
Principal Axis Amp & Dir (ms^{-1}) & (^{o}M)	0.046 (030)	0.046 (010)	0.034 (035)
Residual speed (ms^{-1})	0.017	0.006	0.005
Residual direction (^{o}M)	20	333	13

Calculated mean current speeds suggest that flows are lower at this site than at Eilean Ard, and are strongest at mid-water depths. The strongest currents were also associated with the most frequent current directions, and this association was stronger at mid-water and near the sea bed. Mean currents were also greatest during the flood tide, rather than the ebb. Residual currents tended to flow in a northerly direction, and the strongest residual currents were found at the sea bed.

A weather station was also deployed during the Eilean a'Mhadaidh survey, and winds during the deployment averaged 2.1 m/s, or a 'light breeze'. The maximum recorded wind speed was 5.6 m/s. While winds most frequently came from the northeast, winds were recorded from all directions during the deployment.

Data were collected at Foindle, N 58°23.623' W 005°05.003', between 20/07/2011 and 04/08/2011 and are summarised in Table 13.3.

Table 13.3 Foindle current data measured in 2011

Average Depth	Near-bed (2.7 m above seabed)	Mid-water (13.7 m above seabed)	Sub-surface (15.7 m from seabed)
Mean Speed (ms^{-1})	0.028	0.016	0.017
Maximum Speed (ms^{-1})	0.092	0.064	0.058
Principal Axis Amp & Dir (ms^{-1}) & (^{o}M)	0.044 (55)	0.018 (265)	0.018 (195)
Residual speed (ms^{-1})	0.006	0.009	0.001
Residual direction (^{o}M)	116	271	276

Mean current speeds at Foindle are relatively weak in comparison with Eilean Ard and Eilean a'Mhadaidh, but are generally stronger near the sea bed than at the surface. The direction of current flows at Foindle show semi-lunar periodicity and spring-neap variation, with increasing current speeds observed during spring tides. The strongest currents were generally oriented northeast to southwest, with little difference in speed between the ebb and flood tides. The strongest currents were also in the most frequently recorded current directions. Principal currents were strongest at the sea bed, while the strongest residual currents were found in mid-water. The direction of both principal and residual currents were different at the sea bed from mid-water and sub-surface depths, and had a strong easterly component at the sea bed, and more westerly components at other depths.

A weather station was deployed during the assessment period at Foindle, and recorded a maximum wind speed of 4.6 m/s. Generally, however, winds were considered to be a 'light breeze', averaging 2.3 m/s. Winds came from all quarters, but most frequently from the south and southeast.

In general, the current meter data from Eilean Ard, Eilean a'Mhadaidh, and Foindle suggests that Loch Laxford is moderately to highly 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 Loch Laxford site as 1.0 km (based on a surface principal current amplitude of 0.070 m/s). No distinction is made here for springs and neaps.

Dispersion is an important property of a water body with respect to redistribution of contaminants over time. There are no measurements or published data relating to dispersion in Loch Laxford. Without such data it is difficult to judge what the dispersive environment might be like. However, dispersion is likely to be enhanced by flows around the numerous islands and tidally exposed rocks throughout Loch Laxford.

Dispersion of surface contaminants may be enhanced by wave energy within Loch Laxford. Sources of wave energy are from both short period waves generated within the Loch itself and longer period swells originating from the waters to the west which are open to the North Atlantic Ocean. Even so, the inner portions of the loch are generally considered to be sheltered by islands and rocky reefs in the outer parts of the loch (Bates, *et al*., 2004).

13.2.4 River/Freshwater Inflow

One river, the River Laxford, flows into Loch Laxford at its south-western end, at Laxford Bay. Numerous other small streams and burns flow into Loch Laxford from nearby freshwater lochs, including Loch Elleanach, Loch na Claise luachraich, Loch na Fiacail, Loch Druim na Coilte, and Loch Ghobloch.

The annual precipitation in the area is approximately 2000 mm and the annual freshwater runoff is estimated as 317.5 M $m^3 yr^{-1}$ (Edwards and Sharples 1986). The ratio of freshwater flow to tidal flow is higher than many sea lochs at approximately 1:55 (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 Achfary. This station is situated approximately 12 km to the southeast 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, but rainfall events of > 60 mm d^{-1} were recorded in 2008, 2009 and 2013. Rainfall events of > 30 mm d^{-1} occurred in all months except June, and high rainfall values of 60 mm/d were seen in January, April, May and September. Daily rainfall varied seasonally, from lower values in summer months (June – August) to higher values in autumn and winter months (October – February). Mean rainfall at Achfary peaks in November, and during this month in 2008 a rainfall event of approximately 76 mm d^{-1} occurred. For the duration of the dataset, daily rainfall of below 1 mm occurred on 40% of days, while daily rainfall above 10 mm occurred on 19% 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 Stornoway Airport, located 76 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 Laxford. 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 southwest. Seasonally the strongest winds occurred during the winter and came from this quarter. Typically the wind came from around the south and west throughout the year but the summer also saw winds from the northeast. These two directions lie perpendicular to the axis of the assessment area. Nevertheless, local wind direction in Loch Laxford are likely to be somewhat influenced by the surrounding topography.

13.2.6 Model Assessment

The exchange characteristics of Loch Laxford 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 Laxford 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 13.4

Table 13.4 Summary of annual mean parameter values from the box modelling exercise.

Parameter	Value
Tidal Volume Flux ($m^3 s^{-1}$)	33.7
Estuarine Circulation Volume Flux ($m^3 s^{-1}$)	122.8
Median Flushing Time (days)	13.4
95%-ile Flushing Time (days)	18.3

The ratio of tidal volume flux to estuarine circulation volume flux is less than 0.5 so the estuarine exchange is dominant (Gillibrand, et al., 2013).

The exchange time for the surface and intermediate layers is calculated as 13.4 days which is much longer compared to the tidal prism estimate of 2.7 days (Marine Scotland, 2012). It is known that the tidal prism method overestimates exchange rates and the difference suggests that the exchange environment is less efficient than can be captured by simple volume tidal exchanges. This may be a reflection of the complexity of the Loch system and the high freshwater to tide ratio.

13.3 Hydrographic Assessment

13.3.1 Surface Flow

The site and meteorological data indicate that the discharge of freshwater into the surface will occur primarily at the head of loch, to the east of the assessment area. However, there are numerous smaller rivers discharging from lochs around the perimeter of the assessment area. The meteorological data indicate a moderate seasonal variation in freshwater discharge which will mean that the estuarine exchange has a seasonal variation also. Nevertheless, it is apparent from the tidal to freshwater ratio that freshwater discharge is an important aspect of circulation and exchange in this system.

Loch Laxford is rather complex in terms of the topography of the loch with numerous islands, inlets, shoals and adjoining lochs. Further, tidal flows are found to be rather weak and the freshwater contribution rather high. It is therefore likely that a well-developed surface layer will form in many areas of the loch, particularly towards the head. A distinct fresh surface layer can be more easily influenced by winds giving rise to complex current systems that can vary with depth.

From the current meter records located along the southern shore of Loch Laxford it is clear that the flow of water is rather complex and variable in both speed and direction across the assessment area. It is notable that the current meters were sited close to islands and inlets rather than the main body of the loch which will give rise to the variation between sites. Nevertheless, the general characteristic is that the flows will tend to follow the local bathymetry. A weak cyclonic (anti-clockwise) circulation may develop in the loch, with a somewhat enhanced flow along the northern shore, due to the freshwater input and any discharge from Loch a' Chadh-Fi but there is little evidence to support this. The cumulative transport distance on each phase (flood/ebb) of the tide has been estimated at around 1.0 km within the assessment area.

The residual flows during the period of measurement are typically weak despite the importance of the estuarine circulation. It is uncertain why this is the case and may be related to the rather short deployment periods of the current meters and/or the very local characteristics of the measurement site. Surface residual flows would be enhanced by winds blowing out of the loch, but this would necessitate winds from an easterly direction which are rather infrequent. More likely is a suppression of the surface flow with winds from a westerly direction.

Net transport of contaminants is related to the residual flow documented in Tables 13.1-3. The residual flow in the surface waters of the assessment area are shown to be highly variable and will be related to variation in the localised wind and freshwater conditions. Using a value of residual flow speed measured at the surface (0.013

m/s), the net transport over a tidal cycle of approximately 12 hours would be around 0.5 km. This is less than the transport from tidal flow.

From the current meter measurements in Laxford it is likely that any surface contaminant in the southern part of the loch would be transported along rather complex pathways which may increase the residence time in loch.

13.3.2 Exchange Properties

The box modelling has shown that the flushing time for the surface and intermediate depth waters within the assessment area is around 13 days. This is much less than a simple tidal prism approach and may reflect the complexity of exchange that exists in the assessment area. Winds from the west may further reduce the effective flushing of the loch. Despite there being an apparently strong estuarine flow, the complexity seen in the current meter data and the variability in freshwater discharge suggests that the assessment area can be described as being ‘poorly flushed’.

For a complex system, there rather little available current meter data to adequately describe the circulation and exchange for Loch Laxford. There is also a paucity of measured hydrographic data or descriptive literature on exchange properties for the area. However, it was possible to make a very broad assessment of the likely exchange rates. Consequently, the confidence level of this assessment is LOW.

14. Shoreline Survey Overview

A shoreline survey was conducted at Loch Laxford on the 12-14th May 2014. There was little precipitation prior to the survey and none recorded during the survey.

Six long-line mussel farms were observed in the loch, four of which (Weavers Bay, Sgier Fhadha Baghna Aird Bige and Eilean Ard) were owned by Mr A. Ross, with the remaining two (Eilean an Eireannaich and Loch a' Chadh-Fi) owned by Mr J. Ridgway. All sites were operated by Mr J. Ross. The shore base for the sites was located in Weavers Bay. Harvesting was noted as taking place from July to March. In the future, Mr A. Ross plans to extend the farms at Sgeir Fhanda and Baghna Airde Bige and if these were successful he would remove the Eilean Ard farm.

The shores around Loch Laxford were sparsely populated, with human population concentrated around the bays at Ardmore, Fanagmore, and Foindle. Six septic tanks were observed, one of which (at Portlevorchy) appeared to be malfunctioning. The John Ridgway School of Adventure in Skerricha appeared to have a large septic tank serving a large accommodation block with two wooden dwellings with an outfall pipe discharging 50 m offshore northwest of the tank. A seawater sample taken within a 20 m vicinity of the outfall location returned a low result of 1 *E. coli* cfu/100 ml. A second ST was observed west of the Adventure centre however it was not clear whether it was associated with the centre and whether it remained in use. Only the mussel shore-base was noted at Weavers Bay with no associated discharges observed.

At Fanagmore, the harvester identified that four of the five dwellings had STs to soakaways, with the fifth house using a new form of ST utilising aeration. A salmon farm shore-base consisting of offices, service buildings and accommodation was also located in the south corner of Fanagmore Bay, where two fish cages were observed. No septic tanks or outfalls were observed in the vicinity of these buildings.

Holiday accommodation was noted in Ardmore, at An Annaite (multi-person accommodation blocks) and at Skerricha (associated with the John Ridgway School of Adventure Centre).

Small numbers of boats, including people in kayaks, were observed during the survey.

Seventeen sheep and sheep droppings were observed on the hillside at Ardmore. No other sheep, cattle or livestock droppings were noted during the survey. Improved grassland was observed in the immediate vicinity of the dwellings or farm buildings around the loch.

Eight watercourses were sampled and measured during the survey. The majority had low sample results of 10 and <10 *E. coli* cfu/100 ml, including the River Laxford. Two watercourses had higher contamination levels; an unnamed watercourse (60 *E.*

coli cfu/100 ml) approximately 800 m southwest of the Eilean Ard fishery and the Allt a Ghleannain (360 *E. coli* cfu/100 ml) southeast of the Weavers Bay fishery.

Birds were the only wildlife observed, with species including Greylag geese (some with goslings), cormorants, common gulls, eider ducks, Great black–backed gulls, black guillemots, oystercatchers and common sandpipers.

Summary observations are shown in Figure 14.1.

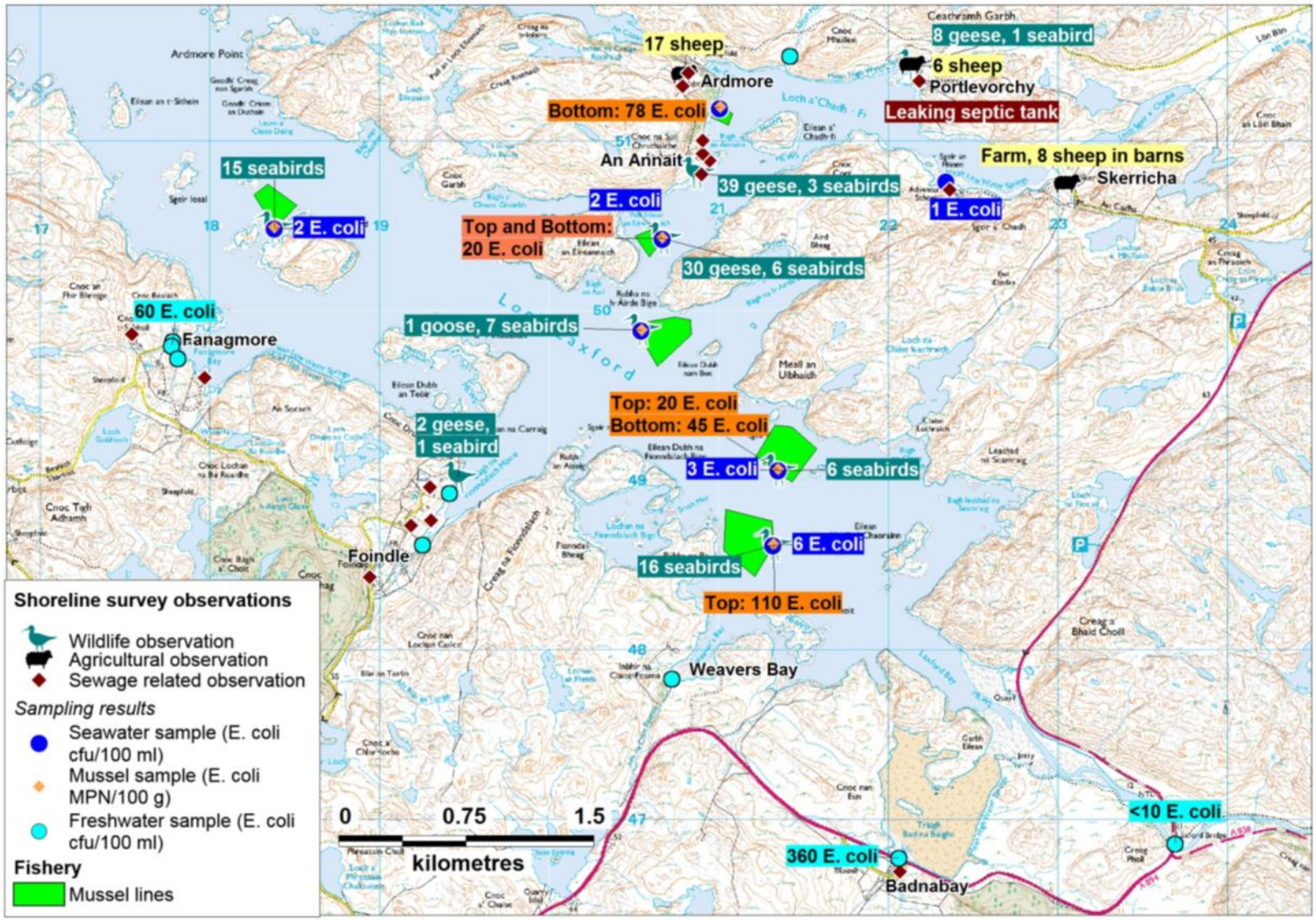

Figure 14.1 Map of shoreline survey observations at Loch Laxford

15. Bacteriological Survey

A bacteriological survey was undertaken at Loch Laxford 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. Sampling was undertaken from the upper 3 m of the lines. The locations are shown in the map in Figure 15.1. The results, together with the geometric mean and maximum values for these at each site, are given in Table 15.1.

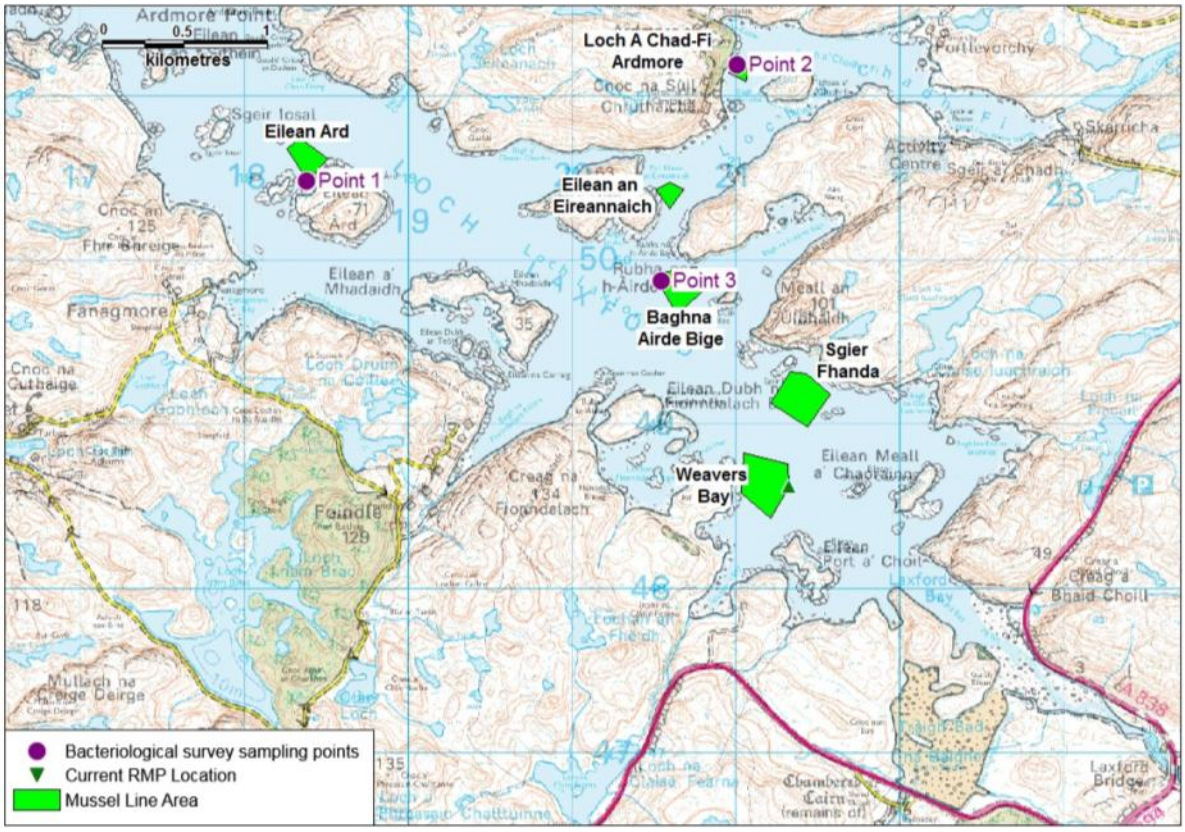

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Figure 15.1 Bacteriological survey sampling locations

Table 15.1. Bacteriological survey results

Sample point	Site name	NGR	*E. coli* MPN/100 g				
			13/05/14	02/07/14	15/07/14	Geometric mean	Maximum
1	Eilean Ard	NC 1838 5049	20	<18[1]	<18	<18	20
2	Loch a Chad – Fi Ardmore	NC 2101 5120	110	45	490	134	490
3	Baghna Airde Bige	NC 2054 4988	<18	<18	230	28	230

[1]< values were assigned a nominal value of 10 for the determination of the geometric mean

The highest geometric mean and maximum *E. coli* values from the three sets of samples were seen at sample point 2 (Loch à Chad-Fi, Ardmore).

16. Overall Assessment

Fishery

There are six active mussel longline sites spread widely around Loch Laxford and Loch a' Chadh-Fi. Cultivation commenced at the Eilan an Eirannaich site after a period of disuse.

Human sewage impacts

The human population around the loch is small. However, the population thatn is there, together with the associated sewage discharges, is mainly concentrated at Ardmore/Annait (within Loch a' Chadh-Fi), Fanagmore (on Fanagmore Bay) and Foindle (on Bàgh na Fionndalach Mòire). During the shoreline survey, a septic tank and discharge pipe to the loch were observed at the outdoor activity centre located on the shore of inner Loch a' Chadh-Fi.

Agricultural impacts

Sheep are the predominant livestock in the area. From the distribution observed during the shoreline survey, the greatest impact is expected at the Loch a' Chadh-Fi and Eilean an Eireannaich sites.

Wildlife impacts

Seabirds and geese are expected to be the predominant source of faecal contamination from the wildlife perspective. Although these will affect all sites, there may be greater impact at those nearer the mouth of the loch (Eilean Ard and possibly Loch a' Chadh-Fi, Eilean an Eireannaich and Baghna Airde Bige).

Seasonal variation

Some holiday accommodation is located at Ardmore and the outdoor adventure centre is nearby. Seasonal variation in human inputs is therefore likely to mainly affect the Loch a' Chadh-Fi and Eilean an Eireannaich sites. Sheep and seabird numbers will be greatest during spring and summer and so seasonal affects from these may be seen at Loch a' Chadh-Fi (sheep and birds), Eilean an Eireannaich (sheep and birds) and Eilean Ard (birds).

Rivers and streams

The greatest amount of faecal contamination from the watercourses is associated with those that discharge at the head of the loch. These will principally affect the Weavers Bay and Sgier Fhanda sites. However, increased loadings in many of the watercourses may be seen after rainfall and, if this occurs, these may impact at the Loch a' Chadh-Fi and Eilean Ard sites. No significant correlation was seen between *E. coli* results from samples taken at the Weavers Bay site and rainfall. Only about a 0.2 ppt difference in salinity was

seen between subsurface and depth during CTD casts undertaken during the shoreline survey.

Movement of contaminants

The topography and bathymetry of the loch, and the current flows within it, are complex. Currents are weak and the maximum transport distance over a flood or ebb tide is anticipated to be approximately 1 km. Surface flow may be suppressed by westerly winds. Transport due to residual flow over a tidal cycle would be approximately 0.5 km. Therefore, contaminants are only likely to impact at the mussel farms located relatively close to sources.

Temporal and geographical patterns of sampling results

In general, the sample results from the Weavers Bay site have remained relatively stable over time although there have been slight periodic variations in the trend line. A large proportion of results have been reported against the RMP, and no geographic assessment was undertaken on that data.

A bacteriological survey was undertaken at three sites and this yielded higher average and maximum results at Loch a' Chadh-Fi compared with Eilean Ard and Baghna Airde Bige. Seawater samples taken during the shoreline survey yielded low *E. coli* results 0 to 6 *E. coli* cfu/100 ml) with the highest result being obtained from a sample taken at the Weavers Bay site.

Conclusions

Overall, the Loch a' Chadh-Fi mussel farm is closest to known sewage and farm animal sources and may also be impacted by contamination from seabirds and geese. Results from the bacteriological survey showed higher levels of *E. coli* at this site than at two others.

The predicted maximum transport distance means that most of the other farms are at the limit of, or beyond, the limit of transport of contamination from known point sources and watercourses and are only likely to be subject to intermittent contamination from diffuse sources.

17. Recommendations

Production area

It is recommended that some areas of the loch, where there are known to be concentrations of diffuse sources and there is no mussel production, be excluded from the production area. These include Laxford Bay (mouth of the Laxford River), Baghna Fionndalach Moire (Foindle), Fanagmore Bay (Fanagmore) and the eastern end of Loch a' Chadh-Fi. The recommended area is therefore the area within the lines drawn between NC 1723 5100 and NC 1879 5100 and between NC 2200 4800 and NC 2211 4823 and between NC 1956 4921 and NC 2012 4920 and between NC 1808 4995 and NC 1842 4980 and between NC 2219 5105 and NC 2195 5103, and extending to MHWS.

RMP

It is recommended that the RMP is moved to the Loch a' Chadh-Fi site in order to better reflect the sources identified in that area. The recommended location on that site is: NC 2099 5115.

Tolerance

The recommended tolerance is 40 m to allow for some movement of the mussel lines.

Depth of sampling

The recommended depth of sampling is 1-3 m, given that no significant freshwater impact has been demonstrated at the mussel farms.

Frequency

The recommended monitoring frequency is monthly.

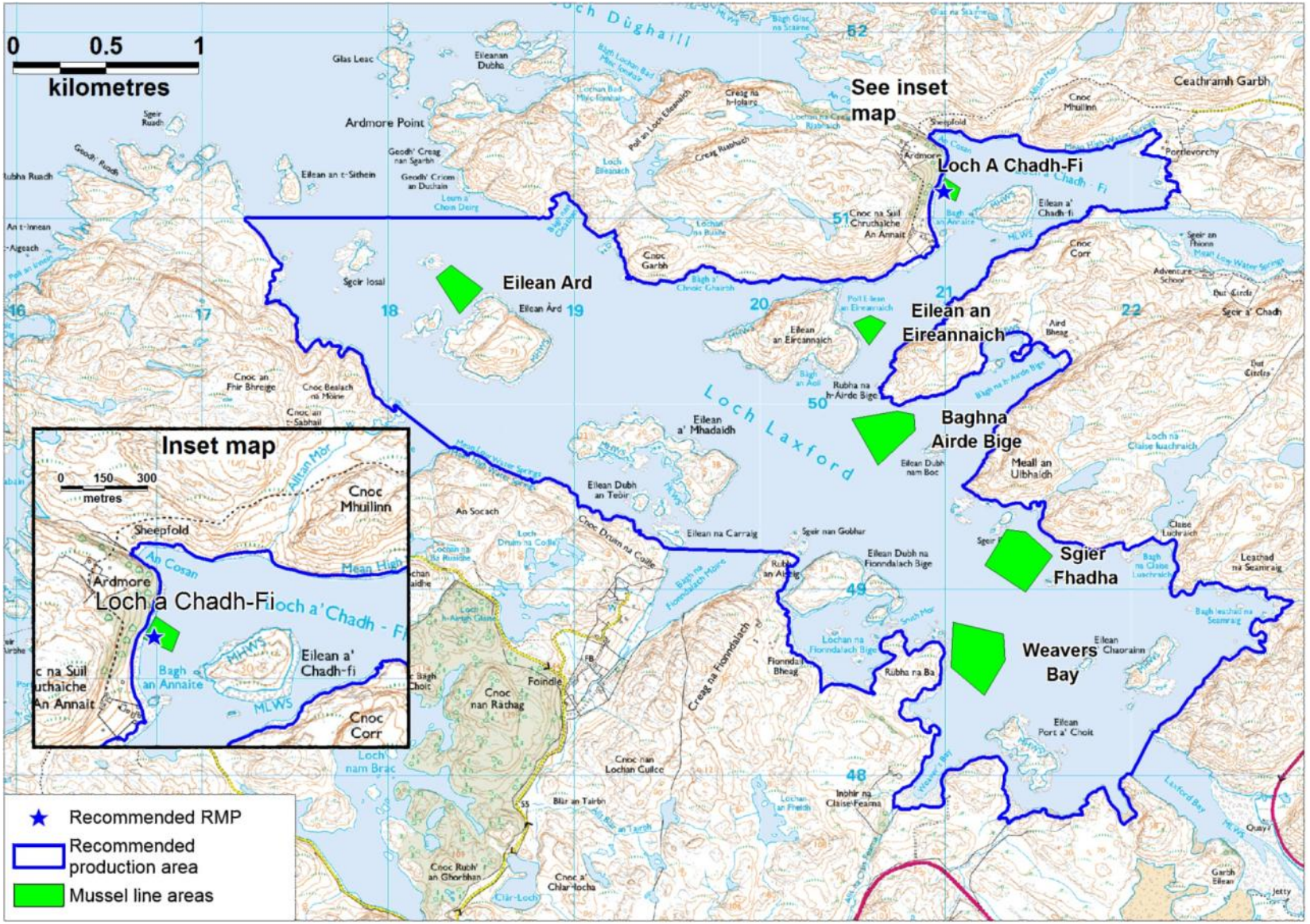

Figure 17.1 Map of recommendations at Loch Laxford

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4. **Hydrographic Section Glossary**
5. **Shoreline Survey Report**
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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 x 10^4 CFU (colony forming units) *E. coli* per gram dry weight of faeces (Lisle *et al* 2004).

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

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

Cetaceans

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

A variety of cetacean species are routinely observed around the west coast of Scotland. Where possible, information regarding recent sightings or surveys is gathered for the

production area. As whales and dolphins are broadly free ranging, this is not usually possible to such fine detail. Most survey data is supplied by the Hebridean Whale and Dolphin Trust or the Shetland Sea Mammal Group and applies to very broad areas of the coastal seas.

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

Birds

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

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

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

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

Deer

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

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

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

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

Other

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

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

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2. Tables of Typical Faecal Bacteria Concentrations

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

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

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

Table 2 – 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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3. Statistical Data

One-way ANOVA: logec versus Season

Method

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

Equal variances were assumed for the analysis.

Factor Information

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

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Season	3	0.9707	0.3236	1.44	0.240
Error	56	12.5433	0.2240		
Total	59	13.5140			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.473272	7.18%	2.21%	0.00%

Means

Season	N	Mean	StDev	95% CI
1	18	1.1676	0.3055	(0.9441, 1.3911)
2	15	1.472	0.682	(1.227, 1.717)
3	13	1.356	0.505	(1.093, 1.619)
4	14	1.1871	0.3264	(0.9337, 1.4405)

Pooled StDev = 0.473272

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Season	N	Mean	Grouping
2	15	1.472	A
3	13	1.356	A
4	14	1.1871	A
1	18	1.1676	A

Means that do not share a letter are significantly different.

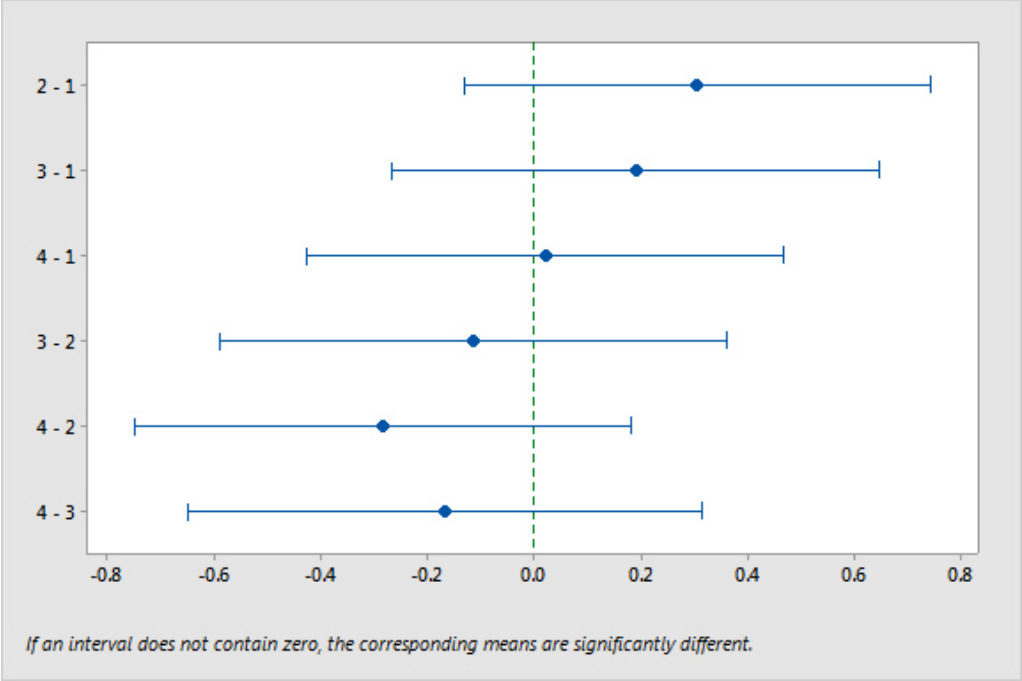

Figure 1 Differences in Means of LogEC from Tukey Simultaneous 95% CIs test

4. Hydrographic Assessment Glossary

The following technical terms may appear in the hydrographic assessment.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5. Shoreline Survey Report

Shoreline Survey Report

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

Document Number	B0067_Shoreline 0031

Revision History

Revision	Changes	Date
A	Issue for internal review	26/05/2014
B	Second issue for internal review	29/05/2014
C	Third issue for internal review	13/06/2014
01	First formal issue to Cefas	16/06/2014
02	Second formal issue with comments addressed from Issue01	07/072014
03	Third formal issue with comments addressed in Issue 02	08/07/2014
04	Fourth formal issue incorporating harvester's clarification	14/07/2014

	Name & Position	Date
Author	Debra Brennan Peter Lamont	26/05/2014
Checked	Andrea Veszelovszki	14/07/2014
Approved	Andrea Veszelovszki	14/07/2014

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

Production area:	Loch Laxford
Site name:	Baghna Airde Bige; Eilean Ard; Loch A Chad-Fi, Ardmore; Sgeir Fhadha, Weavers Bay and Eilean an Eireannaich
SIN:	HS-167-316-08 HS-167-317-08 HS-167-318-08 HS-167-319-08 HS-167-320-08
Species:	Common Mussels (*Mytilus edulis*)
Harvesters:	Mr John Ross and Mr John Ridgway
Local Authority:	Highlands Council, Highland Sutherland
Status:	Existing area
Date Surveyed:	12-14th May 2014
Surveyed by:	Debra Brennan, Peter Lamont
Existing RMP:	NC 2134 4858

Area Surveyed

The shoreline and private discharges at Ardmore (incl. An Annaite), Portlevorchy, Skerricha, Fanagmore, Foindle, and Badnabay were surveyed approximately 6 km in total. There were no WC facilities at the only building in Weavers Bay. Nine watercourses were sampled. Six sites of mussel lines on Loch Laxford were sampled.

Weather

Scattered showers but mostly dry weather was recorded in the 48 hrs prior to survey.

On the day one of the survey the weather was dry and mostly sunny with approximately 10% cloud cover. Temperature ranged between 12 to 15 degrees Celsius with wind speed of 4.7- 4.9 knots of south-easterly direction. Sea state: slight.

Day two weather was mostly dry with scattered showers with and 70% cloud cover. Temperature ranged from 11 to 14 degrees Celsius with wind speed of 1.9- 3.1 knots in a southerly direction. Sea state: slight.

Day three weather was dry with 100% cloud cover. Temperature ranged from 11 to 14 degrees Celsius with a wind speed of 1.6 – 2.9 knots in a southerly

direction. Sea state: slight.

Stakeholder engagement during the survey

The harvester and operator John Ross was not available to meet up with the team during the survey but he informed us prior to the survey about the ownership and arrangements of all six sites within the loch. Ms Anne Grant the local sampling officer was also off work at the time of the survey and therefore Mr Sandy Fraser was covering for her and met up with the team on the morning of the boat work. He was very helpful regarding information on the fishery. Mr Fraser confirmed the site of the RMP. Mr Alec Ross was the skipper of the boat for the day and was very helpful and

informative regarding the mussel farms and helped the team obtain the mussel samples.

Fishery

The fishery at Loch Laxford consists of six arrays of common mussel lines (Fig. 2 & 3). Out of these Mr Ross owns four sites (Weavers Bay, Sgeir Fhada, Baghna Aird Bige and Eilean Ard, and the remaining two sites (Eilean an Eireannaich and Ardmore) are owned by Mr John Ridgway, but all operated and run by Mr John Ross. The lines at all sites are double-headed longlines, with 5-8 m droppers (Figs. 15 & 16). Mr Ross informed the team that the site at Eilean Eireannaich was taken over by him from Mr Ridgway about three years ago and now mussels are growing there.

The base for the mussel farm operation is in Weavers Bay, where there is a large shed and outside hard standing for new mussel rope. The mussels are harvested from July through to March. Mr Alec Ross informed the team that there are future plans to extend the arrays at Sgeir Fhadha and possibly Baghna Airde Bige, and if this was successful, the array at Eilean Ard would be removed. In addition, in the loch there is a salmon farming operational base in the south corner of Fanagmore Bay at waypoint 88 from where the team observed fish cages at two positions (NC 1876 5008 & NC 1794 4970).

Sewage Sources

Loch Laxford has an indented shoreline with numerous bays and eighteen islands and islets. Habitations are sparse in this area. Small collections of dwellings and farm buildings are present in six of the seven bays that were visited by the team: Ardmore (incl. An Annaite), Portlevorchy, Skerricha, Fanagmore, Foindle and Badnabay (Fig. 2 & 3). The team were told that there were no facilities at the seventh site, the shellfish farm store in Weavers Bay. Five private discharges direct to sea or freshwater were listed in the survey plan, one at An Annaite, one at Badnabay and three at Fanagmore. Of these, two were observed and confirmed while the tank, but not the outfall pipe, was observed at Badnabay (waypoint 107). Two at Fanagmore were from dwellings on the hillside where vegetation and fencing and private ground prevented confirmation. The two watercourses running near these two dwellings were sampled below at the shore according to the survey plan (LLFW3 & 4, waypoints 83 and 85). An additional private discharge direct to the loch, which was not in the survey plan, was noted at Skerricha and a seawater sample taken as close to the outfall as possible (LLSW1, waypoint 23). All other observed private discharges are listed in the observation table (Table 1).

An Annaite and Ardmore on the north side of the loch encompass a range of stone and wooden buildings some of which are used for accommodation.

At An Annaite on the hillside, about 400 m above the shore, there is one confirmed permanent dwelling and two other houses. The septic tank for the permanent habitation and the drainage for the second dwelling could not be located by the team. The presumed septic tank for the third, the westernmost (a traditional croft house according to local information) is shown in Figure 5.

On the more level ground above the shore are a number of buildings and sheds including a second confirmed permanent habitation (Fig. 6 with drainage shown in Fig. 7) whose owner the team spoke with and who confirmed a nearby green wooden dwelling as a holiday house (Fig. 8). Other buildings in the group in this area appeared to include a multiperson accommodation block (seen in Fig. 5). These buildings lie in private grounds and the team were unable to directly ascertain their drainage arrangements. A small shed above the shore at the eastern edge of the settlement (seen in Fig.9, east of waypoint 6) also appeared to be accommodation but with no observable drainage.

At Ardmore the tank associated with a third, northernmost permanent habitation, was shown to the team by the owner. This tank, according to the owner, is constructed of local stone and drains to a soakaway. The drain to the soakaway could not be located by the team. There is a very small watercourse that drains off the hill into a gully and then to the sea and which passes close by this tank (Fig. 10). About 100 m to the south and west of this permanent habitation are two stone buildings and a wooden shed. These appear to be used for accommodation but no drainage arrangements could be confirmed by the team.

Portlevorchy to the east of Ardmore consists of two dwellings (Fig. 11). The westernmost is a traditional cottage and it was unclear if it was permanently occupied. The septic tank for this traditional house was broken and showed signs, at the time of the team visit, of previous recent leaking as illustrated in Figure 12. The other, a newer property, was occupied at the time of the survey and appeared to be a permanently occupied dwelling. The drainage arrangement for this newer house lay within the garden ground and could not be observed by the team.

Skerricha comprised two barns at the surfaced road end (Fig. 13). A habitation lies about 50 m north of the barns. At 0.8 km west along an unsurfaced track lies an Adventure Centre comprising of a large, wooden accommodation block and two wooden dwellings. A large, block work septic tank serves the accommodation. The outfall of the block work tank runs into the sea about 50 m northwest of the tank in a 100 mm diameter plastic soil pipe (Fig. 14). The only other septic tank observed was a disconnected fibreglass tank at the top of the shore west of the large block work tank.

Fanagmore lies in the west of the loch, along the southern shore and comprises of three separate dwellings and two agricultural buildings to the west of the bay. The dwelling nearest the shore, near waypoint 80, has an outfall pipe running into the loch in a small bay at the rear of the property. The team were unable to visit the pipe due to steep rock along the shore. The property was unoccupied at the time of the visit. The outfall arrangements of the septic tanks (soakaway or stream discharge) for the other two properties in the west of Fanagmore near waypoint 87 could not be confirmed as investigation would have meant encroaching on the curtilage of the houses.

In the south corner of the bay there is a salmon farm service building and office building with an accommodation building nearby. The office building at the salmon farm service site has an external soil pipe but the team were unable to locate the

septic tank. The accommodation building lies about 100 m uphill near waypoint 89. No external soil pipes were observed on this building and the team were unable to find the main drain route and could not establish the location of the septic tank. The nearby watercourse lies in a deep rock cutting about 80 m down a steep slope from the building and 30 m down slope from the salmon farm office block.

Foindle lies above a V-shaped bay running southwest to northeast on the southern shore of the loch. On day three of the survey the team fortuitously met Alec Ross again at his home in Foindle where he was very helpful with information regarding septic tank drainage arrangements of his own and the neighbouring dwellings. Four habitations are situated on the west side of the glen with a fifth, relatively new house observed from waypoint 100, to the south of the bay and on the east side of the watercourse that enters the loch. This property has a new form of septic tank utilising aeration according to Mr Ross, who also informed the team that the four other septic tanks at Foindle each had a soakaway.

Weavers Bay is the base for the mussel cultivation in the loch. The team were informed by an employee that the storage shed, situated on the east side, does not have toilet facilities and no septic tank or outflow pipes were observed by the team. The watercourse Allt na Clais Fearna was sampled by the team as required in the survey plan. No habitations were observed upstream of this burn nor are illustrated on the OS map.

Badnabay is situated on the south shoreline near to the head of Loch Laxford and comprises two habitations with associated agricultural barns and some outbuildings. The septic tank beside the stream Allt a' Ghleannain for the northernmost dwelling nearest the road was observed from the old road. No septic tank was observed by the team in the vicinity of garden ground of the second property. Both properties are surrounded in their immediate vicinity by improved grazing.

Seasonal Population

There is an Outdoor Adventure Centre at the road end 0.8 km west of Skerricha (John Ridgway School of Adventure).

A course of ten people in kayaks were observed (Fig 17) by the team from the boat on Tuesday when the shellfish samples were being obtained. Local residents informed the team that a proportion of houses surrounding the loch were holiday lets, however it was not obvious how many houses were used for this purpose.

Boats/Shipping

A large yacht and several smaller boats were present at Ardmore, with the yacht out of the water. A small boat propelled by outboard engine was also seen travelling from Skerricha to Ardmore

Ten kayakers from the Ardmore Adventure School were seen on the Tuesday from the fish farm boat. No other commercial or leisure boats were observed on the loch during the survey.

Farming and Livestock

The only improved grasslands were observed in the immediate vicinity of the dwellings or farm buildings around the loch. No cattle were observed at any of the seven shore sites surveyed. There were seventeen sheep on the hillside at Ardmore. No fresh sheep droppings were observed at any of the sites visited other than Ardmore.

Land Use

The majority of the area is untamed rough hillside with improved grassland grazing restricted as mentioned to the immediate vicinity of dwellings.

Land Cover

Much of the shore is steep and rocky with some parts of the shore walks being inaccessible. Bedrock shows in many small patches on the hillsides with the rock area exposed being about 25% of the land cover. There are a few wooded areas on parts of the shoreline, mostly birch.

Watercourses

The major watercourse is the River Laxford in the southeast corner of the loch. Four named watercourses: Allt Loch na h-Airigh Glaise, Allt na Clais Fearna, Allt a' Gheleannain and Alltan Mòr, and four unnamed watercourses were also sampled.

River Laxford was sampled about 30 m upstream of Laxford Bridge. Although this relatively large river has a wide catchment there are few habitations along its length or surrounding the several lochs from which the river arises. The region upstream from the bridge was not included in the survey.

Wildlife/Birds

Over the three survey days the following birds were observed:

Over forty Greylag geese (*Anser anser),* some with goslings*;* twenty two Cormorants (*Phalacrocorax carbo);* sixteen Common Gulls (*Larus canus*); seven Eider Ducks (*Somateria mollissima*); four Great Black–backed Gulls (*Larus marinus*); two Black Guillemots (*Cepphus grille*); three Oystercatchers (*Haematopus ostralegus*) and two Common Sandpipers (*Actitis hypoleucos*). No other wildlife was observed around the loch during the survey.

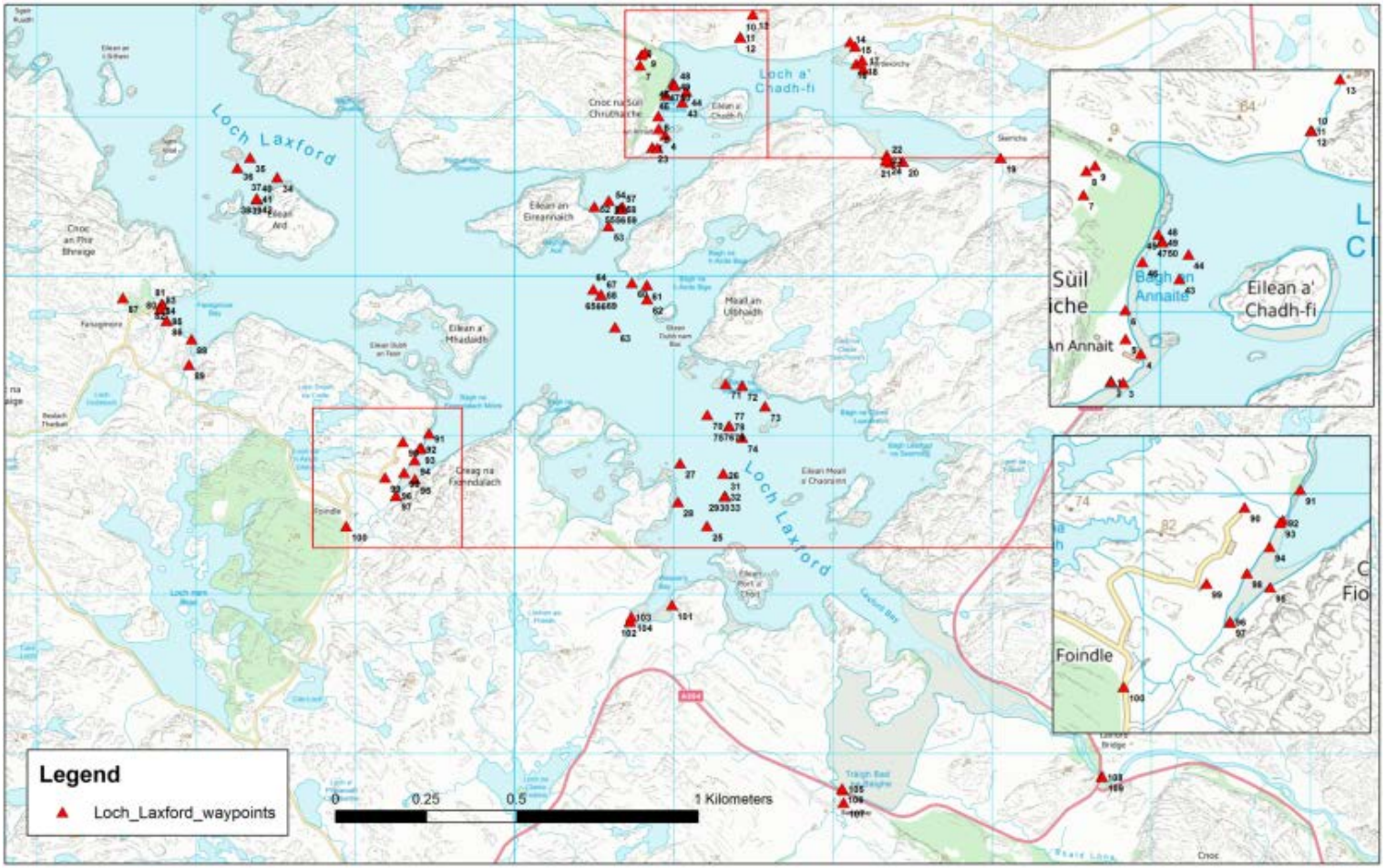

Figure 1. Loch Laxford waypoints

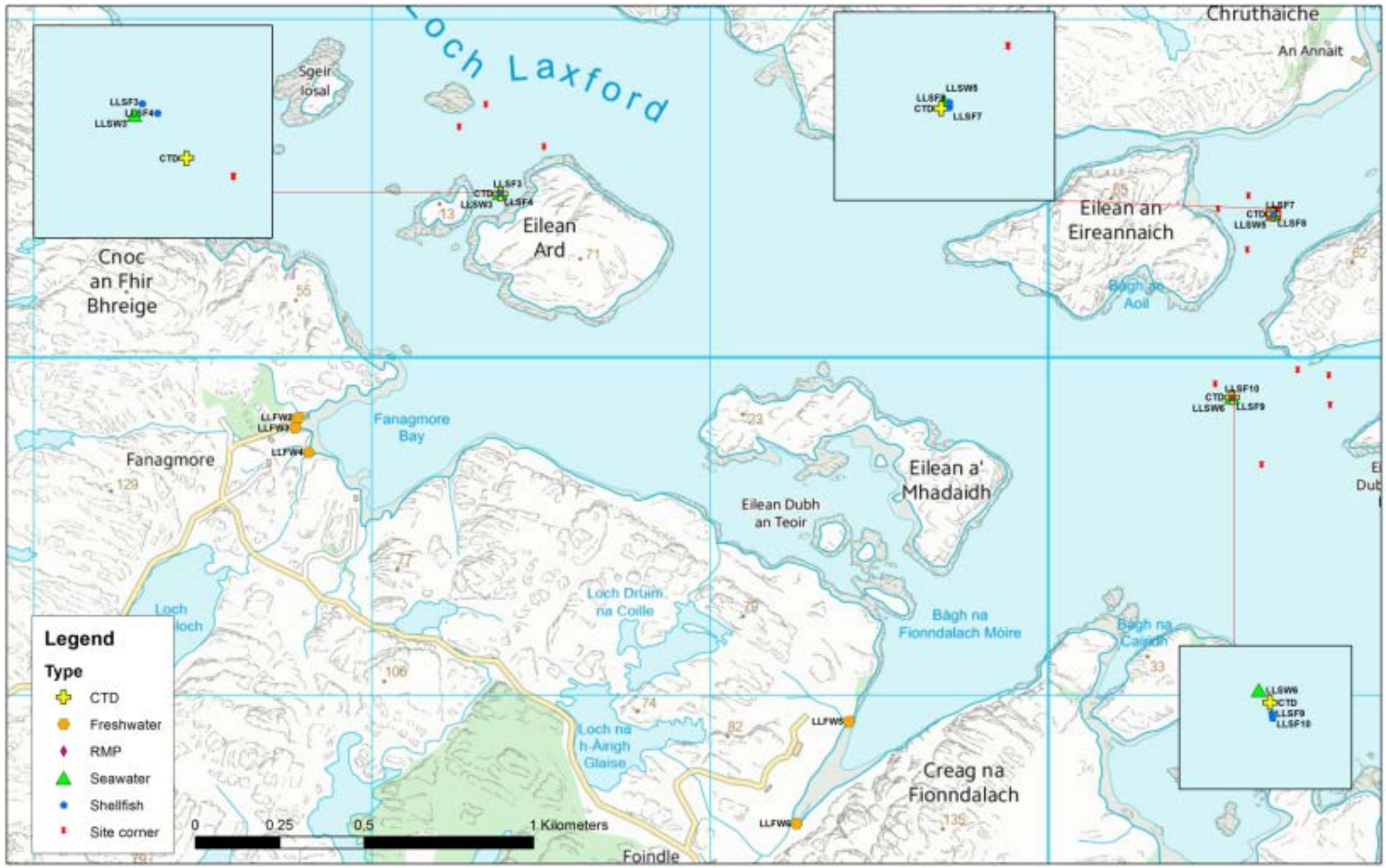

Figure 2. Loch Laxford samples west

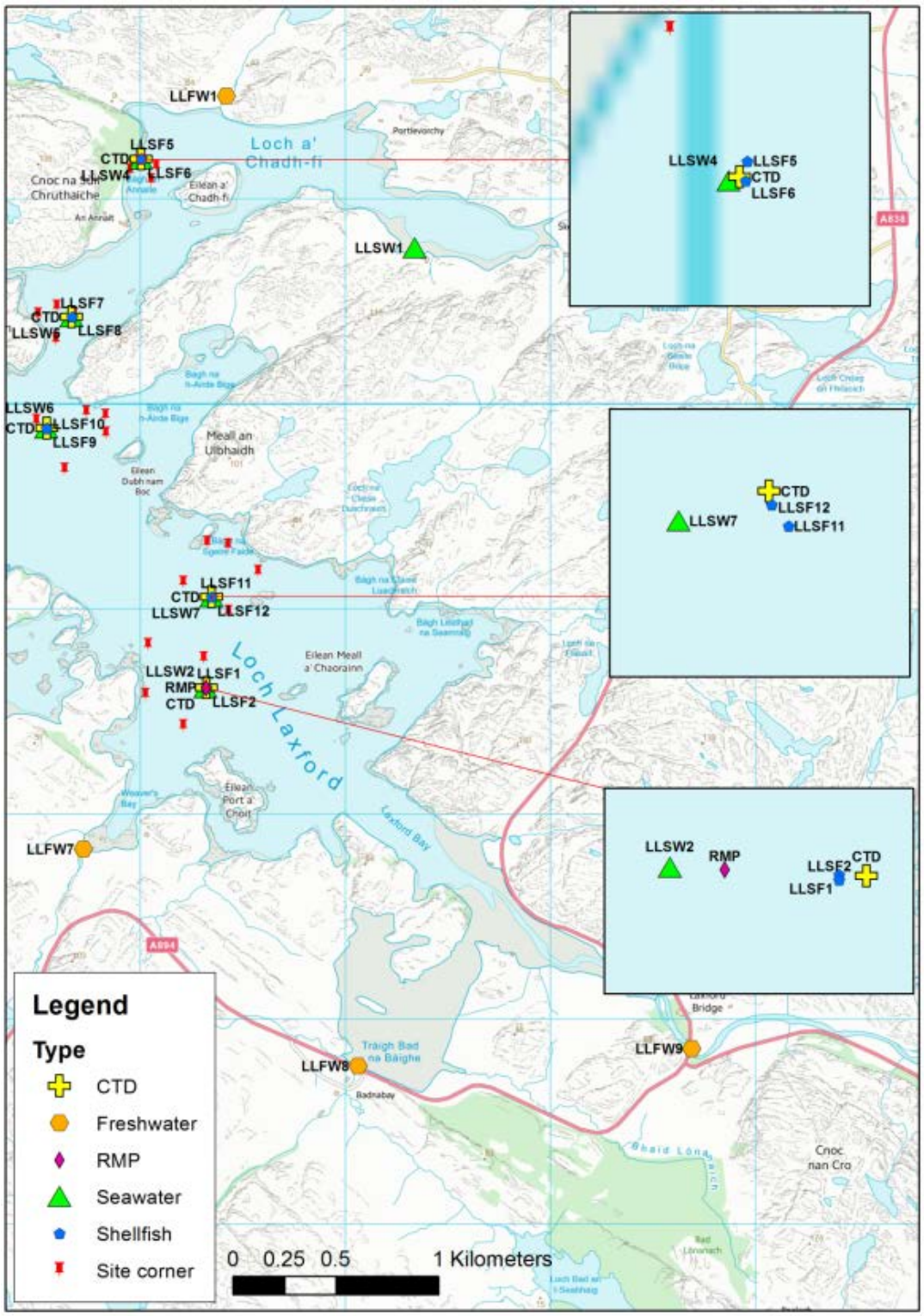

Figure 3. Loch Laxford samples east

Table 1 Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
1	12/05/2014	11:35	NC 20864 50809	220865	950810			Start of shore survey first section Ardmore (An Annaite, SW end of Ardmore section)
2	12/05/2014	11:36	NC 20864 50807	220864	950808	Fig. 4		Three habitations on hillside approximately 400 m above shore with four just above shore plus several sheds. Wildlife: 28 adult Greylag geese on shore grass with 11 goslings, 2 Common Gulls and 1 Oystercatcher.
3	12/05/2014	11:41	NC 20898 50805	220898	950806	Fig. 5		Site of westernmost croft house on hillside and presumed septic tank visible as concrete slab in the foreground. Depression downhill in grass with seepage at top of shore. No sign of pipe.
4	12/05/2014	12:00	NC 20947 50884	220947	950885	Fig. 6&7		Septic tank from new house above shore shown as private discharge on survey plan. Tank effluent carried down beach by 5 cm alkathene pipe to below sea level at the time of survey. Flow not observed. No further access along shoreline from this point as the shore is steep, rocky and covered in seaweed.
5	12/05/2014	12:05	NC 20905 50926	220905	950926			Concrete tank with corrugated iron covering in field below three uphill houses.
6	12/05/2014	12:08	NC 20903 51005	220904	951006	Fig. 8&9		Block work septic tank below green wooden habitation. Neighbour informed the team that the house was rarely occupied. No associated onshore outfall observed.
7	12/05/2014	12:29	NC 20788 51323	220788	951324			Square, upturned fibreglass tank covering concrete base, below wooden habitation (30 m uphill) and 3 m from the south end of a wooden shed/possible accommodation. No associated outfall pipework observed.
8	12/05/2014	12:34	NC 20796 51390	220796	951390			17 sheep on hillside above loch.
9	12/05/2014	12:35	NC 20820 51404	220821	951404	Fig. 10		Septic tank of pointed local stone. Owner informed team that effluent runs into soakaway. Small watercourse immediately below tank draining from land above.
10	12/05/2014	13:10	NC 21419 51500	221419	951500		LLFW1	Planned freshwater sample LLFW1. Sample associated with waypoint 11.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
11	12/05/2014	13:14	NC 21416 51501	221417	951501			Watercourse draining steeply down into loch. Sample taken approximately 300 m above shoreline due to difficult shore access. Watercourse bank to bank = 2.75 m. Large boulders throughout watercourse made it necessary to measure three widths across one section. 1) width 0.48 m, depth 8 cm, flow 0.571 m/sec SD = 0.012; 2) width 0.14 m, depth 7 cm, flow 0.222 m/sec, SD = 0.007; 3) width 0.20 m, depth 6 cm, flow 0.671 m/sec, SD = 0.008.
12	12/05/2014	13:24	NC 21417 51500	221417	951501			End of Ardmore shore survey.
13	12/05/2014	13:30	NC 21497 51643	221497	951644			Extra waypoint taken at foot bridge.
14	12/05/2014	13:51	NC 22107 51470	222108	951471	Fig. 11		Start of second shore survey section at Portlevorchy. Photo shows overview.
15	12/05/2014	13:54	NC 22141 51442	222141	951443			Small watercourse running onto rocky shore from small valley above. Two houses >50 m above shoreline. Six sheep, eight greylag geese and one oystercatcher.
16	12/05/2014	13:58	NC 22146 51332	222147	951333			No outflow pipes visible entering the loch below the two houses.
17	12/05/2014	14:02	NC 22193 51299	222194	951300			End of second shore walk section at Portlevorchy.
18	12/05/2014	14:06	NC 22183 51356	222183	951357	Fig. 12		On return from the shore to the van a septic tank in the field was observed below the westernmost house, outwith the fenced garden ground, approximately 80 m above shoreline seen by the team whilst walking back to the road. Damaged pipe and tank top with sewage leak onto grass.
19	12/05/2014	14:28	NC 23053 50743	223054	950743	Fig. 13		Start of third section at Skerricha. Small watercourse running past two farm barns onto shore at the head of the loch. One peacock and eight sheep in the barns.
20	12/05/2014	14:40	NC 22439 50719	222440	950720			Small watercourse running onto shore from between wooden habitations at Ardmore Adventure School.
21	12/05/2014	14:43	NC 22361 50714	222361	950714	Fig. 14		Large concrete septic tank (6.4 x 2.5 x 1.5 m, LxWxH outside dimensions) at Ardmore Adventure School with >50 m outfall pipe running into loch.
22	12/05/2014	14:44	NC 22337 50723	222338	950724			Disused and disconnected fibreglass septic tank at top of shore with no inlet or outlet connections.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
23	12/05/2014	14:46	NC 22338 50760	222339	950760		LLSW1	Unplanned seawater sample, LLSW1, taken close to concrete septic tank outfall approximately 30 m from shore.
24	12/05/2014	14:49	NC 22335 50732	222335	950732			End of third shore survey section at Skerricha.
25	13/05/2014	9:42	NC 21209 48429	221209	948430	Fig. 15		Start of boat work at mussels arrays. Mussel array Weavers Bay, SE corner. Array of 9 lines with 6 m double headed droppers (according to harvester).
26	13/05/2014	9:44	NC 21310 48759	221311	948759			Mussel array Weavers Bay, NE corner.
27	13/05/2014	9:46	NC 21039 48824	221039	948824			Mussel array Weavers Bay, NW corner.
28	13/05/2014	9:47	NC 21026 48581	221027	948582			Mussel array Weavers Bay, SW corner.
29	13/05/2014	9:54	NC 21319 48615	221319	948616		LLSW2	Planned seawater sample LLSW2
30	13/05/2014	10:00	NC 21323 48615	221324	948616		CTD	CTD 10 m.
31	13/05/2014	10:00	NC 21322 48615	221323	948616		LLSF1	Planned shellfish sample from 0.5 m depth (top of line).
32	13/05/2014	10:00	NC 21322 48615	221323	948616		LLSF2	Planned shellfish sample from 6.0 m depth (bottom of line according to harvester).
33	13/05/2014	10:01	NC 21320 48615	221320	948616		RMP	Confirmed site of RMP. Wildlife 6 eider ducks, 1 great black-backed gull, 7 common gulls and 2 cormorants.
34	13/05/2014	10:20	NC 18508 50619	218509	950619			Mussel array Eilean Ard, SE corner. Array of 6 lines with 8 m droppers (according to harvester).
35	13/05/2014	10:21	NC 18336 50744	218337	950745			Mussel array Eilean Ard, NE corner.
36	13/05/2014	10:23	NC 18258 50678	218258	950679			Mussel array Eilean Ard, NW corner.
37	13/05/2014	10:24	NC 18381 50483	218382	950483			Mussel array Eilean Ard, SW corner.
38	13/05/2014	10:29	NC 18378 50485	218378	950486		LLSW3	Planned seawater sample LLSW3.
39	13/05/2014	10:33	NC 18380 50484	218380	950484		CTD	CTD 10 m.
40	13/05/2014	10:34	NC 18378 50486	218378	950486		LLSF3	Planned shellfish sample 0.5 m top of line LLSF3.
41	13/05/2014	10:34	NC 18379 50485	218379	950486		LLSF4	Planned shellfish sample 8.0 m bottom of line according to harvester, LLSF4.
42	13/05/2014	10:36	NC 18379 50487	218379	950488			Wildlife observed at Eilean Ard 11 Cormorants, 2 Greater Black-backed Gulls, 1 Eider Duck and 1 Black Guillemot.
43	13/05/2014	10:55	NC 21053 51091	221053	951091	Fig. 16		Mussel array Ardmore, Loch A Chad-Fi, SE corner. Array of 4 lines and 6 m double headed droppers (according to harvester).

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
44	13/05/2014	10:57	NC 21078 51159	221078	951160			Mussel array Ardmore, Loch A Chad-Fi, NE corner
45	13/05/2014	10:58	NC 20995 51214	220996	951214			Mussel array Ardmore, Loch A Chad-Fi, NW corner
46	13/05/2014	10:59	NC 20951 51138	220951	951139			Mussel array Ardmore, Loch A Chad-Fi, SW corner
47	13/05/2014	11:04	NC 21003 51193	221004	951193		LLSW4	Planned seawater sample LLSW4.
48	13/05/2014	11:07	NC 21005 51193	221006	951194		CTD	CTD 10 m.
49	13/05/2014	11:10	NC 21006 51196	221007	951196		LLSF5	Planned shellfish sample 0.5 m top of line LLSF5.
50	13/05/2014	11:11	NC 21006 51193	221006	951193		LLSF6	Planned shellfish sample 6.0 m bottom of line according to harvester, LLSF5.
51	13/05/2014	11:22	NC 20592 50474	220593	950475			Mussel array Eilean Eireannaich NE corner. Array of 3 lines with 5 m droppers.
52	13/05/2014	11:23	NC 20502 50435	220503	950436			Mussel array Eilean Eireannaich NW corner.
53	13/05/2014	11:24	NC 20589 50314	220589	950315			Mussel array Eilean Eireannaich SW corner.
54	13/05/2014	11:25	NC 20677 50434	220678	950434			Mussel array Eilean Eireannaich SE corner.
55	13/05/2014	11:27	NC 20665 50424	220666	950425		LLSW5	Planned seawater sample LLSW5.
56	13/05/2014	11:30	NC 20665 50423	220665	950423		CTD	CTD 10 m deployed twice to confirm profile had been recorded.
57	13/05/2014	11:35	NC 20666 50423	220667	950424		LLSF7	Planned shellfish sample from 0.5 m depth (top of line) LLSF7.
58	13/05/2014	11:36	NC 20666 50424	220667	950424		LLSF8	Planned shellfish sample from 5 m depth bottom of line (according to harvester) LLSF8.
59	13/05/2014	11:37	NC 20669 50422	220669	950423			Wildlife 3 Comorants, 3 Common Gulls. Approximately 30 Greylag Geese flying overhead.
60	13/05/2014	11:50	NC 20737 49958	220738	949959	Fig. 17		Mussel array Baghna Airde Bige N point. Array of 4 lines (normally 6 lines) with 6 m droppers. Kayakers out on water.
61	13/05/2014	11:51	NC 20830 49942	220830	949943			Mussel array Baghna Airde Bige NE point.
62	13/05/2014	11:51	NC 20833 49855	220834	949856			Mussel array Baghna Airde Bige SE corner.
63	13/05/2014	11:53	NC 20631 49678	220631	949679			Mussel array Baghna Airde Bige SW corner.
64	13/05/2014	11:54	NC 20494 49917	220494	949917			Mussel array Baghna Airde Bige NW corner.
65	13/05/2014	11:56	NC 20542 49882	220543	949882		LLSW6	Planned seawater sample LLSW6.
66	13/05/2014	12:01	NC 20543 49881	220544	949881		CTD	CTD 10 m.
67	13/05/2014	12:01	NC 20543 49880	220544	949880		LLSF9	Planned shellfish sample 0.5 m top of line, LLSF9.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
68	13/05/2014	12:02	NC 20543 49880	220544	949880		LLSF10	Planned shellfish sample 6.0 m bottom of line (according to harvester) LLSF10.
69	13/05/2014	12:08	NC 20544 49884	220544	949884			Wildlife: 4 Comorants, 3 Common Gulls, 1 Greylag Goose.
70	13/05/2014	12:18	NC 21210 49128	221211	949129			Mussel array Sgeir Fhanda SW corner. Array of 8 lines with 6 m droppers.
71	13/05/2014	12:19	NC 21327 49323	221327	949323			Mussel array Sgeir Fhanda NW corner.
72	13/05/2014	12:20	NC 21429 49311	221429	949311			Mussel array Sgeir Fhanda N point.
73	13/05/2014	12:21	NC 21574 49181	221574	949182			Mussel array Sgeir Fhanda NE corner.
74	13/05/2014	12:22	NC 21430 48985	221430	948986			Mussel array Sgeir Fhanda SE corner.
75	13/05/2014	12:24	NC 21347 49057	221347	949058		LLSW7	Planned seawater sample LLSW7.
76	13/05/2014	12:29	NC 21348 49058	221349	949058		CTD	CTD 10 m.
77	13/05/2014	12:30	NC 21349 49057	221349	949058		LLSF11	Planned shellfish sample 0.5 m top of line LLSF11.
78	13/05/2014	12:30	NC 21348 49058	221349	949058		LLSF12	Planned shellfish sample 6.0 m bottom of line (according to harvester) LLSF12.
79	13/05/2014	12:31	NC 21348 49056	221349	949056			Wildlife observed at Sgeir Fhanda: 2 Common Gulls, 1 Great Black-backed Gull, 1 Comorant, 1 Oystercatcher and 1 Black Guillemot. End of boat work sampling.
80	14/05/2014	10:18	NC 17786 49825	217786	949825			Start of shoreline survey section at Fanagmore Bay.
81	14/05/2014	10:19	NC 17781 49820	217782	949820		LLFW2	Planned freshwater sample LLFW2. Sample associated with waypoint 82.
82	14/05/2014	10:20	NC 17783 49821	217784	949822	Figs. 18&19		Concrete pipe 30 cm diameter. Flow width 12 cm, depth 1 cm. Flow measured with jug 2 L in 4 sec = 30 L/min. Watercourse running from hillside through pipe under road onto shoreline. One house by shore at road end with pipe into loch beyond steep rocky headland.
83	14/05/2014	10:31	NC 17772 49791	217773	949791		LLFW3	Planned freshwater sample LLFW3. Sample associated with waypoint 84.
84	14/05/2014	10:34	NC 17771 49790	217772	949790			Watercourse running down from hillside through small wooded glen onto shore. Width 44 cm, depth 4 cm. Flow measured by jug at waterfalls - 1st fall 2 L in 3 sec = 40 L/min; 2nd fall 2 L in 4 sec = 30 L/min = 70 L/min total. Fish farm cage approximately 1 km from shore.
85	14/05/2014	10:48	NC 17812 49718	217813	949719		LLFW4	Planned freshwater sample LLFW4. Sample associated with waypoint 86.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
86	14/05/2014	10:48	NC 17812 49719	217813	949719	Fig. 20		Watercourse running down small glen from Loch Gobhloch. Width 80 cm, depth 4 cm. Flow 0.330 m/s; SD0.009; 0.266 m/s; SD 0.004; 0.350 m/s SD 0.004. No sign of outflow pipe on shoreline (dwelling on hillside, 150 m above shoreline). Fish cage just off the shore. Access difficult from last part of shore to the west of the bay because of a deer fence so the team drove around by road.
87	14/05/2014	11:28	NC 17538 49862	217539	949863			Dwelling with septic tank and soakaway.
88	14/05/2014	11:39	NC 17970 49603	217970	949604	Fig. 21		Salmon farm slipway. Large building with no pipes visible onto shore. Second building housing office has soil pipe external to the east wall. Septic tank was not observed.
89	14/05/2014	11:47	NC 17955 49443	217955	949444			Watercourse in steep sided gorge was observed by the team from this waypoint at about 50 m. Dwelling on opposite (uphill) side of the roadway had no obvious signs of a septic tank or external soil pipe. End of survey section.
90	14/05/2014	12:06	NC 19298 48959	219299	948960			Start of shoreline survey section at Foindle. Septic tank to soakaway from house on hillside. A single group of two salmon farm cages 200 m to 300 m offshore.
91	14/05/2014	12:15	NC 19462 49011	219462	949012			Start of shoreline walk. Start of wildlife observations: 2 Greylag Geese and 1 Cormorant.
92	14/05/2014	12:20	NC 19411 48922	219411	948922		LLFW5	Planned freshwater sample LLFW5. Sample associated with waypoint 93.
93	14/05/2014	12:33	NC 19402 48913	219402	948914			Watercourse running down small gully to loch. Width 30 cm, depth 2 cm. Flow estimated by jug from three outlets 400 ml in 8 s = 3 L/min plus 600 ml in 30 s = 1.2 L/min plus 1200 ml in 20 s = 3.6 L/min. Total flow = 7.8 L/min.
94	14/05/2014	12:41	NC 19372 48843	219372	948843			Boat noost on shore. (a hollow at the edge of a beach, where a boat is drawn up).
95	14/05/2014	12:47	NC 19373 48723	219374	948724			Eastern limit of surveyed shoreline at Foindle.
96	14/05/2014	12:54	NC 19255 48619	219256	948620		LLFW6	Planned freshwater sample LLFW6. Sample associated with waypoint 97.
97	14/05/2014	13:00	NC 19255 48622	219256	948622	Fig. 22		Watercourse from glen onto shore. Width 1.8 m, depth 7 cm. Flow (1) 0.372 m/s SD 0.003, (2) 0.343 m/s, SD 0.004, (3) 0.240 m/s, SD 0.008

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
98	14/05/2014	13:07	NC 19304 48765	219305	948765	Fig. 23		Freshwater seepage from grass hillside onto shore. Green algae on upper shore rocks. Dwelling approximately 200 m directly above has septic tank with pipe to apparent soak away.
99	14/05/2014	13:24	NC 19185 48734	219186	948735			Dwelling with soil pipe at rear. The team were informed by Alec Ross, a neighbour, that this house has a septic tank with soak away farther down the hillside
100	14/05/2014	13:47	NC 18941 48429	218941	948430			End of Foindle survey section. The team spoke with Alec Ross, owner of property below the road and were shown his septic tank with soak away. Mr Ross informed the team that the other neighbouring properties all had tanks with soakaways except for a new dwelling built on the other side of the watercourse which has a new form of waste treatment involving aeration.
101	14/05/2014	13:59	NC 20988 47933	220989	947933			Start of Weavers Bay shoreline survey section.
102	14/05/2014	14:08	NC 20722 47827	220722	947828		LLFW7	Planned freshwater sample LLFW7. Sample associated with waypoint 103.
103	14/05/2014	14:15	NC 20725 47827	220726	947827			Watercourse entering Weavers Bay through sparsely wooded glen. Width, at constriction formed by two placed blocks: 77 cm, depth 25 cm, 30 cm. Flow (1) 0.475 m/s, SD 0.007, (2) 0.533 m/s, SD 0.011.
104	14/05/2014	14:16	NC 20733 47860	220733	947860			End of Weavers Bay shoreline survey section.
105	14/05/2014	14:30	NC 22062 46771	222063	946771		LLFW8	Planned freshwater sample LLFW8 at Badnabay. Sample associated with waypoint 106.
106	14/05/2014	14:35	NC 22058 46781	222059	946781			Watercourse from farm and houses flowing under rectangular concrete bridge under roadway onto shore. Width at bridge 3.65 m, depths 7 cm, 5 cm, 6 cm. Flow (1) 0.392 m/s, SD 0.004, (2) 0.435 m/s, SD 0.005, (3) 0.426 m/s, SD 0.007.
107	14/05/2014	14:41	NC 22067 46692	222067	946692			Septic tank marked on survey plan observed 30 m from this waypoint. No outflow pipe seen.
108	14/05/2014	14:54	NC 23689 46855	223690	946856		LLFW9	Planned freshwater sample LLFW9. Sample associated with waypoint 109.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
109	14/05/2014	15:01	NC 23693 46854	223693	946855			River Laxford 30 m upstream of bridge, fast flowing river meandering through rocky and grassy glen to head of loch. Width 5.2 m, depth 40 cm. Flow (1) 0.792 m/s, SD 0.042, (2) 0.537 m/s, SD 0.034. The team were unable to measure flow rate across the whole river course due to depth and speed of current. End of survey work.

Photographs referenced in the table can be found attached as Figures 4-23

Sampling

Seawater and freshwater samples were collected at the sites marked in Figure 2.

All freshwater and all seawater samples on the survey plan were acquired, as well as one additional sample from an outflow pipe associated with WP23.

Twelve common mussel samples were taken in accordance with the sampling plan.

All the samples were transferred to a Biotherm 30 box with ice packs and posted to Glasgow Scientific Services (GSS) for *E. coli*. analysis. One freshwater and one seawater sample was collected and sent to the laboratory on the 12th May, the temperature on arrival at the laboratory was recorded as 3.4 °C. Six seawater and twelve shellfish samples were collected and sent in two separate Biotherm boxes to the laboratory on the 13th May the temperature on arrival at the laboratory was recorded as 6.2°C and 7.4°C. Eight freshwater samples were collected on the 14th May and sent to the laboratory on the 15th May (a 48 hour sample submission extension was in place) the temperature on arrival at the laboratory was recorded as 2.8°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	12/05/2014	LLFW1	NC 21419 51500	Freshwater	<10	
2	14/05/2014	LLFW2	NC 17781 49820	Freshwater	<10	
3	14/05/2014	LLFW3	NC 17772 49791	Freshwater	60	
4	14/05/2014	LLFW4	NC 17812 49718	Freshwater	<10	
5	14/05/2014	LLFW5	NC 19411 48922	Freshwater	<10	
6	14/05/2014	LLFW6	NC 19255 48619	Freshwater	10	
7	14/05/2014	LLFW7	NC 20722 47827	Freshwater	<10	
8	14/05/2014	LLFW8	NC 22062 46771	Freshwater	360	
9	14/05/2014	LLFW9	NC 23689 46855	Freshwater	<10	
10	12/05/2014	LLSW1	NC 22338 50760	Seawater	1	26.56
11	13/05/2012	LLSW2	NC 21319 48615	Seawater	6	29.27
12	13/05/2012	LLSW3	NC 18378 50485	Seawater	2	32.34
13	13/05/2012	LLSW4	NC 21003 51193	Seawater	0	34.69
14	13/05/2012	LLSW5	NC 20665 50424	Seawater	2	31.25
15	13/05/2012	LLSW6	NC 20542 49882	Seawater	0	32.70
16	13/05/2012	LLSW7	NC 21347 49057	Seawater	3	29.45

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	Depth (m)	*E. coli* (MPN/100g)
1	13/05/2014	LLSF1	NC 21322 48615	Common Mussel	0.5	<18
2	13/05/2014	LLSF2	NC 21322 48615	Common Mussel	6.0	<18
3	13/05/2014	LLSF3	NC 18378 50486	Common Mussel	0.5	20
4	13/05/2014	LLSF4	NC 18379 50485	Common Mussel	8.0	45
5	13/05/2014	LLSF5	NC 21006 51196	Common Mussel	0.5	110
6	13/05/2014	LLSF6	NC 21006 51193	Common Mussel	6.0	<18
7	13/05/2014	LLSF7	NC 20666 50423	Common Mussel	0.5	<18
8	13/05/2014	LLSF8	NC 20666 50424	Common Mussel	6.0	78
9	13/05/2014	LLSF9	NC 20543 49880	Common Mussel	0.5	<18
10	13/05/2014	LLSF10	NC 20543 49880	Common Mussel	6.0	20
11	13/05/2014	LLSF11	NC 21349 49057	Common Mussel	0.5	20
12	13/05/2014	LLSF12	NC 21348 49058	Common Mussel	6.0	<18

Salinity Profiles

CTD profiles were taken at six locations in the production area, at each sampling point around the mussel lines (refer to Figure 1 for map locations). The gathered data will be sent to client as a separate document. (See Appendix 6)

Photographs

Fig 4. View of Ardmore and three mussel lines

Fig 5. Photo taken from below westernmost croft house at Ardmore. Presumed septic tank cover in foreground Waypoint 3.

Fig 6. Septic tank with shore outfall. Waypoint 4.

Fig 7. Permitted private shore outfall in 50 mm alkathene pipe. Associated with Waypoint 4.

Fig 8. Confirmed holiday house Ardmore and blockwork septic tank associated with Waypoint 6.

Fig 9. Blockwork septic tank associated with Waypoint 6 looking east.

Fig 10. View showing position of tank associated with Waypoint 9.

Fig 11. Photo taken looking towards Portlevorchy

Fig 12. Westernmost dwelling Portlevorchy, associated with Waypoint 18.

Fig 13. Start of Skerricha shore survey section. Associated with waypoint 19.

Fig 14. Septic tank at Ardmore Adventure School Skerricha shore survey waypoint 21. Insert picture associated with Waypoint 23 and unplanned seawater sample LLSW1. Skerricha shore survey.

Fig 15. Mussel array in Weavers Bay associated with Waypoint 25. [photo from second camera – add one hour]

Fig 16. Double headed mussel lines at Ardmore, Loch A Chad-Fi.

Fig 17. Kayakers from the adventure school at mussel array Baghna Airde Bige.

Fig 18. Concrete pipe road culvert with flow. Location of sample LLFW2, Waypoint 81 & 82.

Fig 19. Blue arrow indicates outflow pipe from property above the shore associated with waypoint 81 & 82.

Fig 20. Salmon cages in Fanagmore Bay.

Fig 21. Salmon farm shed (L) and office building (R), Fanagmore Bay associated with Waypoint 88.

Fig 22. Watercourse running onto shore at Foindle at the head of the bay (Bagh na Fionndalach Moire). Blue arrow shows site of freshwater sample associated with waypoint 97.

Fig 23. Foindle septic tank and apparent soak away at NC 1925 4881. Bottom blue arrow shows seepage onto shore at Waypoint 98.

6. Loch Laxford CTD data

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

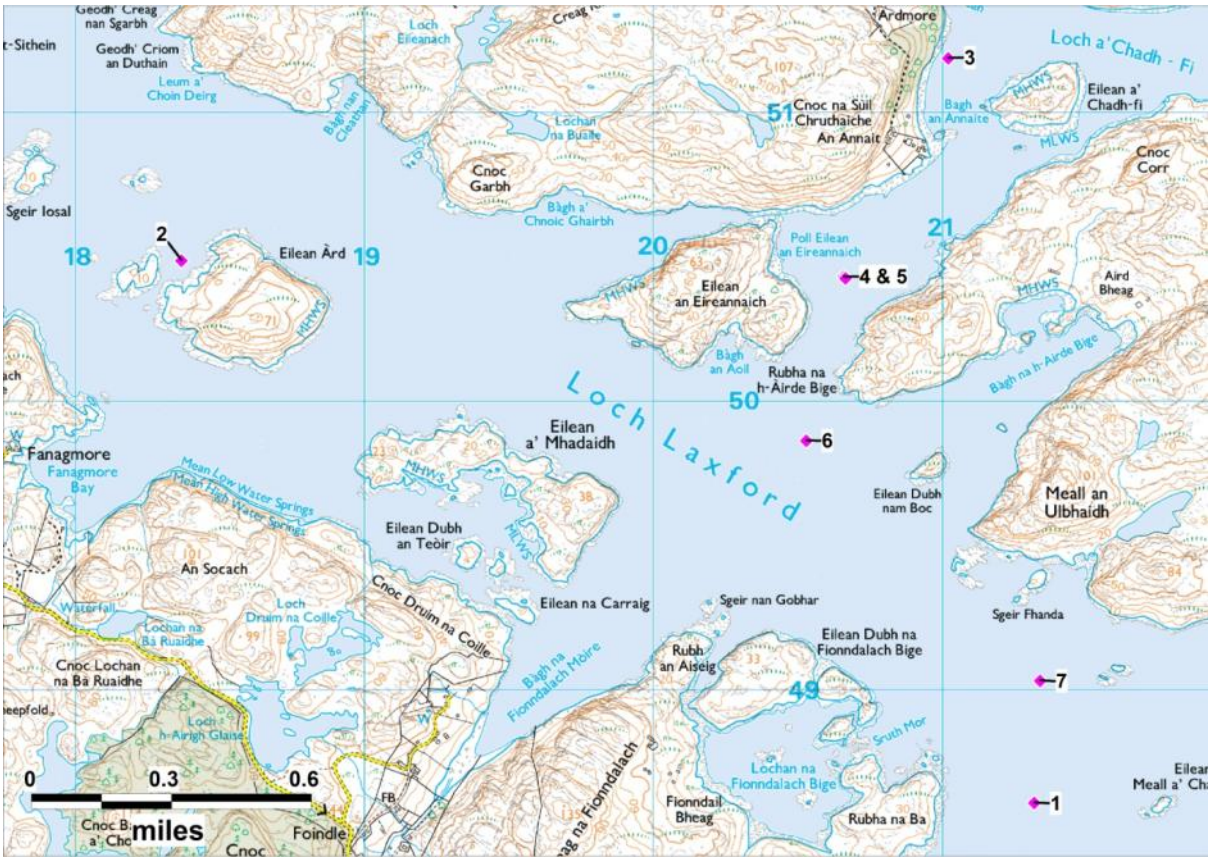

Figure 1 Location of CTD cast

CAST 1

Data Header

% Device	10G100653
% File name	10G100653_20140513_085730
% Cast time (local)	13/05/2014 09:57:30
% Sample type	Cast
% Cast data	Processed
% Location source	GPS
% Start latitude	58.3893181
% Start longitude	-5.0584162
% Start GPS horizontal error(Meter)	4.15000009536743
% Start GPS vertical error(Meter)	6.69000005722046
% Start GPS number of satellites	5
% Cast duration (Seconds)	102.2
% Samples per second	5
Calibration Date	March 2013
Calibration offset for Temperature	-0.033
Calibration offset for Salinity	0.029

CTD data (calibration offsets applied)

Depth (Meter)	Temperature (Celsius)	Salinity (Practical Salinity Scale)
0.149241137	10.52242433	31.03214828
0.447635475	10.54720441	31.6787038
0.745898978	10.45299658	32.2113995
1.043991045	10.3272849	33.14012737
1.341962552	10.31413218	33.24191476
1.639913095	10.27470219	33.31068823
1.937841871	10.17467593	33.40059624
2.235743913	10.08087753	33.50143993
2.533621093	9.946100876	33.56753832
2.831479438	9.801150844	33.60449102
3.129319543	9.699729191	33.67283952
3.427140985	9.619605176	33.72758258
3.724947061	9.56654479	33.77722511
4.022742982	9.526515001	33.79453407
4.320534088	9.444723098	33.79115112
4.618322878	9.38078159	33.78150731
4.916108114	9.313467041	33.79220412
5.213887186	9.279843752	33.8119142
5.511663234	9.257616901	33.80432805
5.809438554	9.231457571	33.80534955
6.10721206	9.189104517	33.80322515
6.404982845	9.154259568	33.81047569
6.702746634	9.091972912	33.84198129
7.000504872	9.046207605	33.83431264
7.298260739	9.01373278	33.84395643
7.596011567	8.994300479	33.86515097
7.893759461	8.968106584	33.85755263

8.191508586	8.936097284	33.83954259
8.48925808	8.91045746	33.83966313
8.787010107	8.897346117	33.80644573
9.084764638	8.886945862	33.80989234
9.382516394	8.886350162	33.82566999
9.555943841	8.890774571	33.84027731

CAST 2

Data Header

% Device	10G100653
% File name	10G100653_20140513_093108
% Cast time (local)	13/05/2014 10:31:08
% Sample type	Cast
% Cast data	Processed
% Location source	GPS
% Start latitude	58.4049444
% Start longitude	-5.1103003
% Start GPS horizontal error(Meter)	15.6800003051758
% Start GPS vertical error(Meter)	18.3799991607666
% Start GPS number of satellites	5
% Cast duration (Seconds)	90.6
% 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)
0.149099472	9.574580513	32.07144847
0.447201292	9.525979234	32.82135939
0.745169379	9.500316759	33.26160811
1.043061635	9.495078544	33.47997526
1.340911578	9.462014255	33.62348687
1.638725326	9.356107929	33.76704629
1.936514317	9.300654164	33.80516016
2.234292306	9.244742971	33.8379771
2.532059375	9.199936925	33.87761546
2.829819219	9.171664095	33.88360363
3.127575048	9.146236206	33.89897955
3.425325878	9.12525938	33.91514127
3.723072772	9.104343371	33.92208684
4.020817344	9.091368998	33.92567826
4.318560725	9.085232447	33.925681
4.616303043	9.074989301	33.92870854
4.914043421	9.052727481	33.93315561
5.211782553	9.021636712	33.92581914
5.509518953	8.972364559	33.93790114
5.807252129	8.926354867	33.93190608
6.104981082	8.894382133	33.95633496

6.402706148	8.880381995	33.95386861
6.700429128	8.866511594	33.966098
6.998148911	8.850356758	33.97297794
7.295866821	8.829222404	33.97210413
7.59358367	8.814548882	33.97212651
7.891298853	8.786822946	33.97528464
8.189011047	8.772303333	33.98699329
8.486721113	8.765036758	33.98665086
8.784430829	8.761157913	33.98486152
9.082140007	8.755790999	33.98654671
9.379847648	8.751771933	33.99352256
9.620185018	8.752387385	33.99674372

CAST 3

Data Header

% Device	10G100653
% File name	10G100653_20140513_100742
% Cast time (local)	13/05/2014 11:07:42
% Sample type	Cast
% Cast data	Processed
% Location source	GPS
% Start latitude	58.4123255
% Start longitude	-5.0654976
% Start GPS horizontal error(Meter)	229.860000610352
% Start GPS vertical error(Meter)	106.860000610352
% Start GPS number of satellites	5
% Cast duration (Seconds)	107.2
% Samples per second	5
Calibration Date	March 2013
Calibration offset for Temperature	-0.033
Calibration offset for Salinity	0.029

CTD data (calibration offsets applied)

Depth (Meter)	Temperature (Celsius)	Salinity (Practical Salinity Scale)
0.148915959	9.615655727	33.70780412
0.44672895	9.60329999	33.70424928
0.744545367	9.58457348	33.72324706
1.042356128	9.556091233	33.74118467
1.340162007	9.535337278	33.75296419
1.637964626	9.522018721	33.75977992
1.935765819	9.517617021	33.75883099
2.233566145	9.51180472	33.76228764
2.531365172	9.498187853	33.76322661
2.829161887	9.469212997	33.7707633
3.126955771	9.440542749	33.77314832
3.424746029	9.414781549	33.78836824
3.722532892	9.394913856	33.79058228
4.020317388	9.381242297	33.79925602

4.318099404	9.37294318	33.80488373
4.615879463	9.365750082	33.81029321
4.913657843	9.359352072	33.81386452
5.211434898	9.353363508	33.81642076
5.509210013	9.338107164	33.8235491
5.806981818	9.320219619	33.83573605
6.104750747	9.299177405	33.8378438
6.402515327	9.258566216	33.85831267
6.70027565	9.221571228	33.85634857
6.998032158	9.186113693	33.87401019
7.295782148	9.130536453	33.89209031
7.593528133	9.097382971	33.88812331
7.891273886	9.080825023	33.88097682
8.189016927	9.053169032	33.90000419
8.486755271	9.038755928	33.91078231
8.784490286	9.008918052	33.91733337
9.080546832	8.998021475	33.92048839

CAST 4

Data Header

% Device	10G100653
% File name	10G100653_20140513_103101
% Cast time (local)	13/05/2014 11:31:01
% Sample type	Cast
% Cast data	Processed
% Location source	GPS
% Start latitude	58.4123255
% Start longitude	-5.0654976
% Start GPS horizontal error(Meter)	96.1800003051758
% Start GPS vertical error(Meter)	30.9300003051758
% Start GPS number of satellites	4
% Cast duration (Seconds)	82
% 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)
0.148949283	9.830160979	33.45848957
0.446816002	9.750288791	33.56459277
0.744663397	9.668666187	33.64345893
1.042498782	9.63773555	33.64368772
1.340333337	9.611981765	33.635824
1.638166836	9.592017139	33.64037711
1.935998449	9.591171279	33.64508391

2.233828346	9.601092818	33.6544213
2.531657945	9.594020525	33.64532686
2.829488821	9.581188664	33.63599162
3.127321392	9.56817105	33.62195468
3.425154217	9.540239527	33.62216121
3.722984315	9.526849639	33.63434696
4.020810548	9.50134129	33.64508808
4.318632097	9.481417553	33.66314567
4.616446983	9.457382049	33.69163592
4.914255118	9.435103686	33.70999962
5.212054826	9.384698392	33.74778062
5.509845874	9.351325351	33.76591506
5.807629849	9.293711323	33.78825271
6.10540413	9.243481251	33.82605525
6.403169772	9.199922784	33.84203746
6.700929624	9.161914901	33.85731013
6.998685049	9.145760141	33.86692616
7.296437604	9.123231946	33.87168608
7.594187266	9.095638676	33.87916179
7.89193431	9.077062699	33.88232964
8.18967875	9.044387435	33.88864651
8.487420281	9.030864763	33.89556184
8.785158782	9.010062736	33.90534831
9.119026498	9.004500341	33.89628298

CAST 5

Data Header

% Device	10G100653
% File name	10G100653_20140513_103339
% Cast time (local)	13/05/2014 11:33:39
% Sample type	Cast
% Cast data	Processed
% Location source	GPS
% Start latitude	58.4123255
% Start longitude	-5.0654976
% Start GPS horizontal error(Meter)	4.1100001335144
% Start GPS vertical error(Meter)	3.75999999046326
% Start GPS number of satellites	6
% Cast duration (Seconds)	68.6
% 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)

0.148954954	9.838962636	33.41150917
0.446825579	9.783527153	33.58146693
0.744673906	9.737647602	33.63775498
1.04251298	9.710867293	33.64465695
1.340349256	9.689242753	33.64916374
1.638184342	9.665833104	33.64263547
1.936020726	9.645513329	33.6254866
2.233855394	9.632124127	33.6476573
2.531686527	9.615037215	33.64723876
2.829517847	9.601804905	33.6366293
3.127349812	9.590350886	33.63336222
3.425182287	9.577357316	33.62400597
3.72301465	9.568678014	33.62679787
4.020843985	9.566922193	33.64553055
4.318670234	9.547329768	33.64652682
4.616494412	9.526498532	33.65231567
4.914314469	9.481443526	33.66606898
5.212123686	9.415636457	33.72171565
5.509915397	9.318801419	33.7835357
5.807695385	9.270754359	33.79198772
6.105467849	9.219806946	33.8264144
6.40323195	9.18820344	33.8456808
6.700991961	9.169161252	33.84905736
6.998749193	9.145495428	33.85840374
7.296502824	9.117466706	33.86720446
7.594253008	9.094037061	33.87524137
7.891999262	9.064806254	33.88808771
8.189744101	9.054699909	33.87668793
8.48748901	9.039675156	33.87936387
8.785230922	9.01860582	33.89275473
9.130205572	9.009072652	33.89619322

CAST 6

Data Header

% Device	10G100653
% File name	10G100653_20140513_105929
% Cast time (local)	13/05/2014 11:59:29
% Sample type	Cast
% Cast data	Processed
% Location source	GPS
% Start latitude	58.4123255
% Start longitude	-5.0654976
% Start GPS horizontal error(Meter)	124.5
% Start GPS vertical error(Meter)	152.229995727539
% Start GPS number of satellites	5
% Cast duration (Seconds)	95.4
% 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)
0.149096006	10.33195518	32.26998164
0.447162179	9.988803104	33.16603501
0.745082977	9.894248476	33.50070881
1.042958455	9.870566309	33.53748464
1.340823266	9.824932226	33.57698321
1.638680321	9.818789718	33.59185552
1.936535207	9.822916856	33.5927039
2.234388114	9.81359608	33.60520873
2.532235359	9.775389669	33.62952772
2.830071626	9.721367209	33.67942359
3.127896982	9.699890181	33.70672162
3.425712307	9.638411014	33.74733098
3.723515299	9.575735497	33.78625106
4.021307086	9.510189625	33.81614869
4.319089077	9.442312535	33.84164264
4.616863415	9.378943	33.8531967
4.91463231	9.332488046	33.86376981
5.212395897	9.302148082	33.88104164
5.510154966	9.284998181	33.89077077
5.80791193	9.266025601	33.88912289
6.105667004	9.238587604	33.89484555
6.403419946	9.205392522	33.89242146
6.701170945	9.176484076	33.8961918
6.998918302	9.160308658	33.91225473
7.296662584	9.146009688	33.91404488
7.59440574	9.139209702	33.91485119
7.892147595	9.12815207	33.91885971
8.189889725	9.123406924	33.90619421
8.48763161	9.103959174	33.91308362
8.891579811	9.103766481	33.91306204

CAST 7

Data Header

% Device	10G100653
% File name	10G100653_20140513_112747
% Cast time (local)	13/05/2014 12:27:47
% Sample type	Cast
% Cast data	Processed
% Location source	GPS
% Start latitude	58.3931225
% Start longitude	-5.0583994
% Start GPS horizontal error(Meter)	6.90999984741211
% Start GPS vertical error(Meter)	10.6899995803833

% Start GPS number of satellites	5
% Cast duration (Seconds)	69.5
% 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)
0.149096006	10.33195518	32.26998164
0.447162179	9.988803104	33.16603501
0.745082977	9.894248476	33.50070881
1.042958455	9.870566309	33.53748464
1.340823266	9.824932226	33.57698321
1.638680321	9.818789718	33.59185552
1.936535207	9.822916856	33.5927039
2.234388114	9.81359608	33.60520873
2.532235359	9.775389669	33.62952772
2.830071626	9.721367209	33.67942359
3.127896982	9.699890181	33.70672162
3.425712307	9.638411014	33.74733098
3.723515299	9.575735497	33.78625106
4.021307086	9.510189625	33.81614869
4.319089077	9.442312535	33.84164264
4.616863415	9.378943	33.8531967
4.91463231	9.332488046	33.86376981
5.212395897	9.302148082	33.88104164
5.510154966	9.284998181	33.89077077
5.80791193	9.266025601	33.88912289
6.105667004	9.238587604	33.89484555
6.403419946	9.205392522	33.89242146
6.701170945	9.176484076	33.8961918
6.998918302	9.160308658	33.91225473
7.296662584	9.146009688	33.91404488
7.59440574	9.139209702	33.91485119
7.892147595	9.12815207	33.91885971
8.189889725	9.123406924	33.90619421
8.48763161	9.103959174	33.91308362
8.891579811	9.103766481	33.91306204