Scottish Sanitary Survey Report

Sanitary Survey Report
Loch Eriboll
HS 139
July 2013

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Partner Organisation

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

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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 common mussel and Pacific oyster fisheries at Loch Eriboll 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.crlcefas.org/gpg.asp). 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.

Loch Eriboll is situated along the north coast of Scotland, approximately 8 km southeast of Durness, the nearest significant centre of population.

The Pacific oyster fishery at Loch Eriboll is inactive. Two mussel farms were present in the southern end of the loch. The harvester reported that juvenile stock had been placed on site and that harvest was anticipated starting in late 2013. A scattering of derelict lines was also reported to be present in the loch. A small number of trestles was present on the intertidal shore near the crofting township of Laid, though no commercial oyster stock was present and there was only a small number of Pacific oysters and common mussels on site for sampling purposes.

The principal sources of faecal contamination to the Loch Eriboll shellfishery are:

- Livestock grazed on crofts along the west shore south of Laid and on the east shore at the farm at Eriboll
- Diffuse pollution from septic tank soakaway systems along the west shore
- Gulls, ducks and other seabirds on or near the farms and/or resting on the floats
- Any overboard discharges from boats or yachts using anchorages near the Laid mussel farm

Due to predicted weak currents within the loch, only sources very near to the shellfish farms are likely to be significant in terms of impact to the bacteriological quality of the shellfish.

Summary of recommendations

As the outer loch is very exposed and not used for shellfish aquaculture, it is recommended that the northern production area boundary be curtailed to better reflect the location of the shellfish seabed lease areas.

Due to the inactive state of the Pacific oyster fishery in Loch Eriboll, it is recommended that classification monitoring not be resumed until such time as a commercial fishery is re-established in the loch.

It is recommended that the RMP for mussels be retained at the trestle location due to its proximity to identified sources of contamination and its accessibility for sampling. However, it is recommended that the RMP be moved to the southern end of the trestles, nearer the watercourse sources to the south.

Further details on the recommendations can be found in the sampling plan, overleaf.

II. Sampling Plan

Production Area	Loch Eriboll Mussels
Site Name	Laid Sample Trestle
SIN	HS 139
Species	Common mussels
Type of Fishery	Long line aquaculture
NGR of RMP	NC 4188 5923
East	241880
North	959230
Tolerance (m)	10
Depth (m)	NA
Method of Sampling	Hand
Frequency of Sampling	Monthly
Local Authority	Highland Council Sutherland
Authorised Sampler(s)	Anne Grant
Recommended production area boundaries	Area bounded by lines drawn from NC 4232 6000 to NC 4400 6000 to NC 4400 5808 and from NC 4000 5621 to NC 4000 5550 to NC 4106 5550 and extending to MHWS

III. Report

1. General Description

Loch Eriboll is a deep, sea loch on the north coast of Scotland, approximately 8 km southeast of Durness. It has a north-easterly aspect with a total length of 15.5 km and ranges from 500 m to 1.5 km in width. It has a maximum depth of 68 m with a mean depth at low water of 26 m. An uninhabited island, Eilean Choraidh (Horse Island), lies within the inner loch.

One of the most remote lochs in Scotland, the shores of Loch Eriboll are largely unpopulated aside from the small crofting village of Laid along the west shore. The location of Loch Eriboll is shown in Figure 1.1.

Figure 1.1 Location of Loch Eriboll

2. Fishery

The fishery comprises separate production areas for two species: common mussels and Pacific oysters. Details of the classified areas are given in Table 2.1.

Table 2.1 Area shellfish farms

Production area	Site	SIN	Species	RMP
Loch Eriboll	Loch Eriboll	HS-139-305-08	Common Mussels	NC 4189 5928
	Loch Eriboll- MacLennan	HS-139-307-08		
	Loch Eriboll-Mathers	HS-139-308-08		
	Loch Eriboll- McGowan	HS-139-309-08		
Loch Eriboll Oysters	Loch Eriboll	HS-139-305-13	Pacific Oysters	NC 4189 5928
	Loch Eriboll- MacLennan	HS-139-307-13		

Both species share the same production area boundaries: the production area boundaries are defined as lying within lines drawn between NC 3994 5550 (Rubh Armil) to NC 4105 5550 and the line between NC 4546 6500 to NC 4905 6500 extending to Mean High Water Springs (MHWS).

Six Crown Estate seabed leases for shellfish aquaculture were identified within the production area boundaries. It was not possible to establish which of these lease areas were associated with the site numbers identified in the 2012-2013 classification document.

The shoreline survey identified two main areas of mussel lines: one area of 6 longlines along the west shore of the loch to the south of Laid and a second area of 6 longlines along the east shore of the loch adjacent to An Druim. These belonged to harvester Mr. John Ross. The sampling officer for the area identified that the harvester had recently brought spat in and anticipated being able to harvest from late 2013 onward.

Due to problems with the harvester's boat, it was not possible for the shoreline survey team to access the mussel farms directly and therefore the locations were observed from shore. Photographs taken of the lines showed they were maintained and some lines appeared to be heavy, suggesting growth on them (Figure 2.1 and 2.2). The shoreline survey report identified that in addition to the two farms mapped, other areas of derelict lines were seen to the NW of Eilean Choraidh and southwest of the mussel farm at Laid. Although the specific locations were not recorded, the estimated locations were determined from photographs taken during the survey. No mussel lines were seen along the east side of Eilean Choraidh, where there are two shellfish leases.

An area of 11 trestles was found in the vicinity of the RMP location. Two bags containing live Pacific oysters were present at the time of survey. Mussels were also sampled from bags on these trestles.

The area of the oyster trestles and the mussel lines observed during the shoreline survey are shown in Figure 2.3.

Figure 2.1 Mussel farm at Laid, Loch Eriboll

Figure 2.2 Mussel farm at An Druim, Loch Eriboll

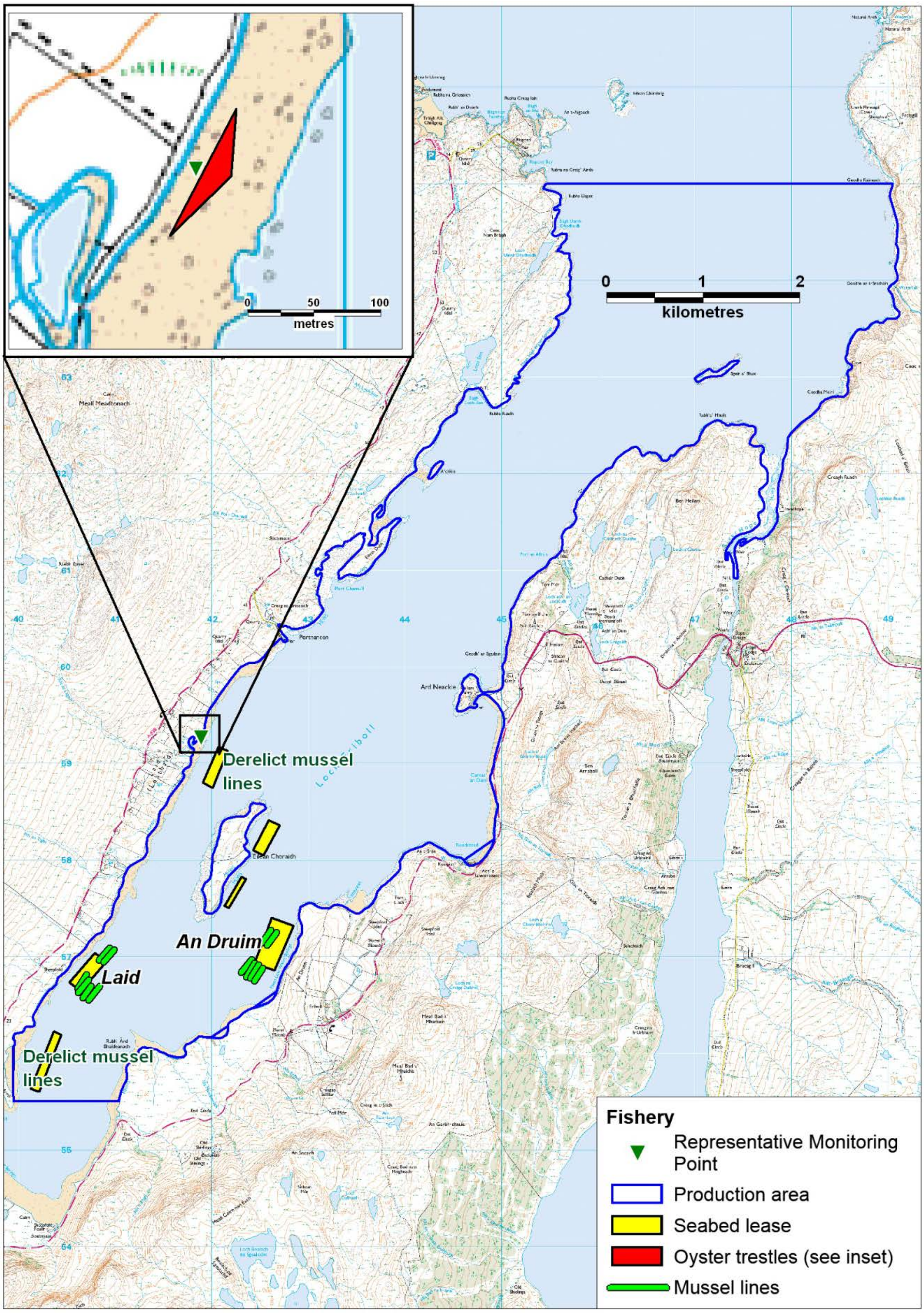


Figure 2.3 Loch Erboll Fishery

3. Human Population

Information was obtained from the General Register Office for Scotland on the population within the census output areas in the vicinity of Loch Eriboll. Detailed data from the 2011 census was unavailable at the time of writing this report, therefore data presented below are from the 2001 census.

The population surrounding the Loch Eriboll area is contained within one large census output area with land area of 639 km^2 and a total population of 152. Figure 3.1 presents a map showing the census output area boundary and population related observations from the shoreline survey.

The crofting village of Laid, the largest centre of population around the loch, is located on the west shore adjacent to the RMP. The sampling officer reported a campsite adjacent to the cafe at Laid that accommodates caravans and tents. Based on a review of satellite imagery, this appears to be located adjacent to one of the B&B's at Laid and has capacity for only a small number of caravans. There is a farm at Eriboll on the east shore near An Druim and a small fish hatchery at the head of the loch. There are approximately 5 self catering cottages and a bed and breakfast in the area, and when occupied these are likely comprise a significant proportion of the local population. A fish hatchery and two cottages are located at Polla, near the head of the loch. A private sewage discharge detailed in Section 4 is listed as being located at Port Chamuil, indicating a dwelling is present.

There is a pier on the eastern shore and another, Portnancon Pier directly opposite on the western shore. There are three anchorages within the production area along the southwestern side of the loch, one of which is close to the Laid mussel lines. The shoreline survey report noted that there is a mixture of small boating activity in Loch Eriboll including fish farm work boats, intermittent fishing from creel boats and some recreational activity. In the past, the loch has been used as a deep water anchorage for large vessels. During the shoreline survey, boats were observed hauled out at the pier south west of Heilam.

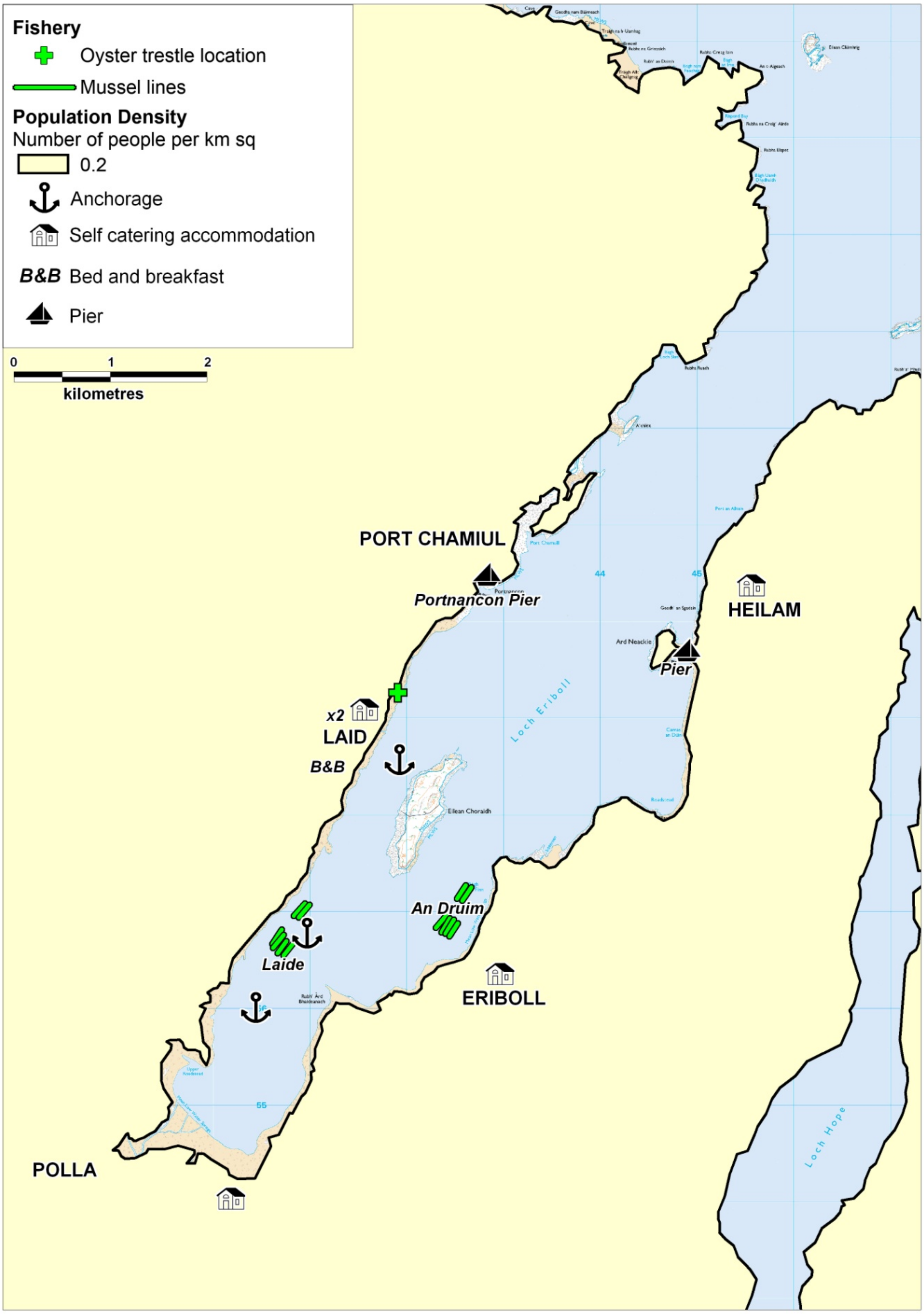


Figure 3.1 Population map of Loch Eriboll

4. Sewage Discharges

Information on sewage discharges to the area around Loch Eriboll 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 or to waterbody), any available dispersion or dilution modelling studies, and whether improvements were in work or planned.

Scottish Water reported no public sewerage assets in the area.

SEPA provided information for 24 discharge consents of which 18 were sewage discharges, all privately owned. All reported grid references were restated to the nearest 10 m for the purposes of presentation in the tables below. These are presented in Figure 4.1. There has historically been no requirement in Scotland to register septic tanks, and current regulations require registration of old tanks on sale of property or installation of new equipment. Therefore, the number of private septic tanks reported in Table 4.1 is likely to be an underrepresentation of the total number of tanks in the area.

Data from SEPA was compared with the discharges listed in the shellfish growing water report for Loch Eriboll (SEPA, 2010). Any discrepancies or discharges missing were queried with SEPA. Records were amended once clarified by SEPA.

The largest reported consent was for septic tank serving a house and 3 caravans with a PE listed as <50. This was queried with SEPA, who advised that when no PE was supplied on the consent application, it was assigned a value as less than the largest permissible PE for the registration. The actual population equivalent is thus likely to be markedly less than 50.

Of the 18 reported sewage discharges, two (Nos. 2 & 17, Table 4.1) discharge directly to the production area and one (No. 10, Table 4.1) discharges into Allt an Lagain which flows into the production area. Water samples taken from the burn and from seawater near the septic tank (No. 10, Table 4.1) returned results indicating little or no faecal contamination.

Three septic tanks with soakaways (Discharges 1, 2 & 3) are located very close to MHWS. Soakaways required a difference in height between the percolation pipes and the water table, to allow for sufficient time in the soils aerobic layers to complete treatment of the effluent. Septic tanks at or near to sea level are unlikely to have this height difference, so effluent entering the production area from these soakaways will not have received significant further treatment through the soil.

No discharge consent information was available for properties along the head and the east shore of the loch, where there are very likely to be septic tanks associated with farms and other properties at the loch head, Eriboll, Kempie, Ard Neackie, and Heilam.

Table 4.1 Sewage discharge consents identified by SEPA

No	Consent Ref.	NGR	Description	Discharge Type	Level of Treatment	PE	Discharge to
1	CAR/R/1077551	NC 4309 6082	Port Chamuil office	Continuous	Septic Tank	5	Soakaway
2	WPC/N/60855	NC 4270 6040	Portnancon	Continuous	Septic Tank	11	Loch Eriboll
3	CAR/R/1027479	NC 4270 6029	New dwelling adj to Portnancon	Continuous	Secondary	5	Soakaway
4	CAR/R/1046879	NC 4230 6030	Tigh na Bo	Continuous	Septic Tank	5	Soakaway
5	CAR/R/1076526	NC 4175 5962	Rose Cottage	Continuous	Septic Tank	5	Soakaway
6	CAR/R/1055073	NC 4161 5954	Rowan Cottage & 3 Caravans	Continuous	Septic Tank	< 50	Soakaway
7	CAR/R/1055228	NC 4157 5951	Rowan House	Continuous	Septic Tank	8	Soakaway
8	CAR/R/1065812	NC 4146 5914	Burnside	Continuous	Septic Tank	5	Soakaway
9	CAR/R/1073591	NC 4133 5902	94 Laid	Continuous	Septic Tank	15	Soakaway
10	CAR/R/1067705	NC 4130 5911	The School House	Continuous	Septic Tank	5	Allt an Lagain
12	CAR/R/1067384	NC 4117 5862	100 Laid	Continuous	Septic Tank	5	Land
13	CAR/R/1076254	NC 4119 5848	105 Laid	Continuous	Septic Tank	5	Soakaway
14	CAR/R/1077987	NC 4105 5831	91 Laid	Continuous	Septic Tank	5	Soakaway
15	CAR/R/1067275	NC 4104 5821	Glenaladale	Continuous	Septic Tank	6	Land
16	CAR/R/1009423	NC 4092 5805	99 Laid	Continuous	Septic Tank	5	Soakaway
17	CAR/R/1055818	NC 4109 5785	101 Laid	Continuous	Septic Tank	5	Loch Eriboll
18	CAR/R/1064914	NC 4082 5754	97 Laid	Continuous	Septic Tank	5	Soakaway
19	CAR/R/1077549	NC 4065 5744	95 Laid	Continuous	Septic Tank	5	Soakaway

The 6 discharges which did not relate to sewage were comprised of one trade effluent discharge, two fresh water fish farms and three marine cage fish farms:

Table 4.2 Other discharge consents identified by SEPA

No	Consent Ref.	NGR	Name	Discharge Type
11	CAR/L/1004987	NC 41085 59179	Laid WTW, Durness, Sutherland, TE to Allt an Lagain	Treated Effluent
-	CAR/R/1085724	NC 38784 54647	Polla FF, Laid, Durness, TE to Allt Coire an Uinnseinn	Fish Farm Effluent
-	CAR/L/1004986	NC 39110 54650	Polla Hatchery FCFF, FE to Loch Eriboll at Strath Beag estuary	Fish Farm Effluent
-	CAR/L/1002080	NC 44750 63050	Loch Sian	Fish Farm Effluent
-	CAR/L/1003109	NC 44560 62470	Sian Bay MCFF, Loch Eriboll	Fish Farm Effluent
-	CAR/L/1003110	NC 44500 58300	Kempie MCFF, Loch Eriboll	Fish Farm Effluent

Discharge 11 pertains to the Laid Water Treatment Works. Water used to backwash the filters may contain faecal indicator bacteria. Effluent goes to Allt an Lagain and this burn showed no evidence of significant faecal contamination at the time of shoreline survey.

The two freshwater fish farms are identified at the head of the loch, on the Amhainn an t-Sratha Bhig. Three marine cage fish farms are also identified in the loch: two in the north of the loch around Loch Sian and one south of Ard Neackie on the east side of the loch. It is unknown whether there are any septic tanks associated with these.

The only sewage-related infrastructure observed during the shoreline survey was a group of septic tanks, partially sunk into concrete and covered by a wooden frame at Portnancon Pier. This is shown in Figure 4.1. This appears to relate to the B&B at Portnancon (No. 2, Table 4.1), which has a PE of 11. No outfall was noted. The dwellings are recorded as holiday cottages so use is likely to be seasonal. This tank lies 1.4 km northeast of the oyster trestles and 3.7 km northeast of the Laid mussel site.

Summary

Loch Eriboll is sparsely inhabited, as reflected in the discharge consents. All sewage infrastructure is privately owned and therefore is assumed to be subjected to primary treatment by septic tanks unless otherwise stated, although in some instances small scale sewage treatment works may have replaced septic tanks. According to SEPA records, the majority of septic tanks discharge to land, with only two recorded as discharging to water body or watercourse. Whilst all reported septic tanks were located around Laid and Portnancon, there are likely to be additional tanks in these areas as well as at the head of the loch and along the eastern shore. However, it is still expected that the largest concentration of septic tanks will be along the west shore. Any impacts from sources along the west shore are likely to be highest at the oyster trestle area and to the north of the Laid mussel farm. The properties at Eriboll and separated from the shore of the loch by a small ridge to the west. This would tend to drive drainage from any soakaway fields northward, reaching the loch approximately 1 km NNE of the An Druim mussel farm.

Sewage input is likely to vary seasonally due to the presence of seasonally occupied dwellings. Irregular use of septic tanks may depress their ability to effectively treat sewage, leading to higher potential impacts from dwellings that are only seasonally occupied.

Discharge-Related Acronyms

FCFF	Freshwater Cage Fish Farm
FE	Final Effluent
FF	Fish Farm
MCFF	Marine Cage Fish Farm
PE	Population Equivalent
ST	Septic Tank
TE	Trade Effluent
WTW	Water Treatment Works (potable)

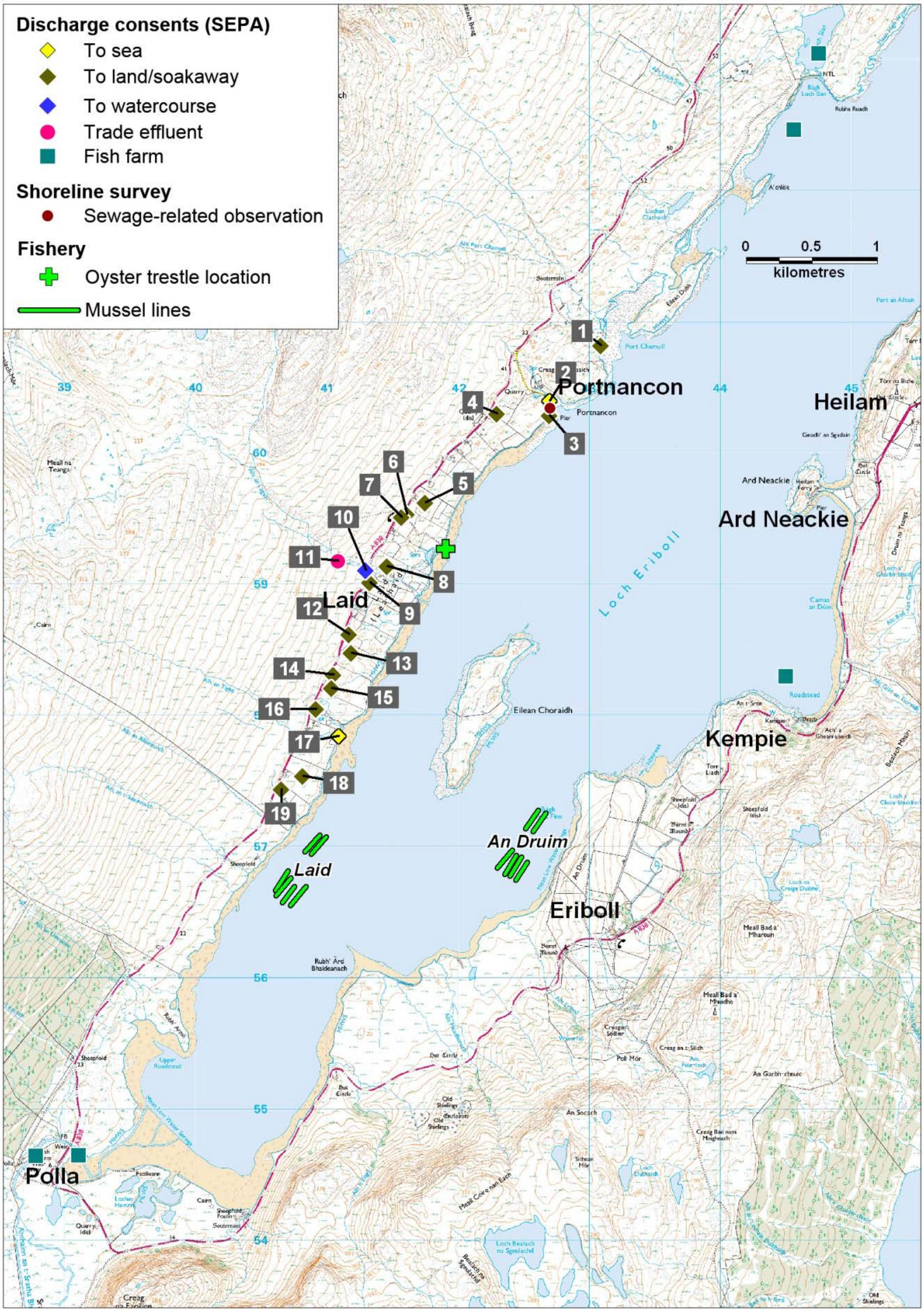


Figure 4.1 Map of discharges for Loch Eriboll

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 production area. The land surrounding Loch Eriboll lies within Durness parish, which has a land area of approximately 580 km^2. Agricultural census data to parish level was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for that parish.

Reported livestock populations for 2012 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 for the Durness agricultural parish along the Loch Eriboll coastline 2012

	Durness	
	583 km^2	
	Holdings	Numbers
Pigs	*	*
Poultry	*	*
Cattle	6	142
Sheep	19	12585
Other horses and ponies	0	0

Due to the large land area of the parish, it is not possible to assess the spatial distribution of the livestock with regard to the fishery within Loch Eriboll. However, the figures do give an idea of the total numbers of livestock over the broader area. Sheep were the predominant type of livestock kept in the area, with an average of 662 animals per holding.

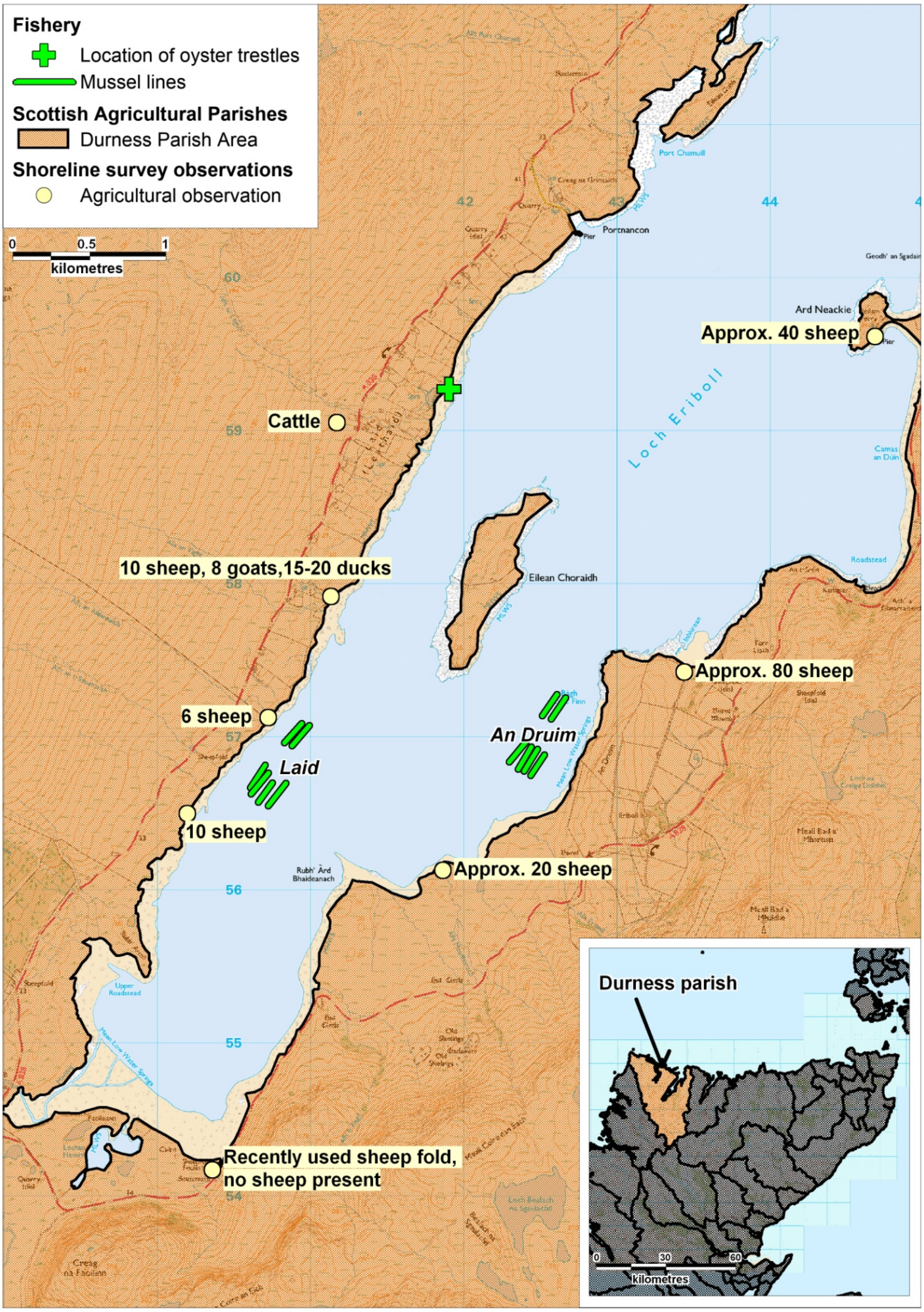
The SEPA Loch Eriboll Growing Waters report (2011) identified that very little of the area is used for agriculture.

The only significant 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 8th and 9th April 2013 (see Table 5.1). 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.

Much of the land around Loch Eriboll is used for rough grazing and sheep were observed grazing on the hills on both sides of the loch. A sheep fold on the southern shore of the loch was observed to have been in recent use, although no animals were present at the time of the survey. An unspecified number of cattle were observed near the settlement of Laid, however were not observed as part of the shoreline survey route. The sampling officer for the area reported that one croft at Laid keeps approximately six pigs and a dozen chickens. Livestock observations correlated broadly with the presence of improved pasture around farms or crofts on both sides of the loch. The majority of animals were seen on the eastern side of the loch, with the largest group around a farm at Kempie, northeast of the An Druim site.

Numbers of sheep will be approximately double during late spring following the birth of lambs, and decrease again in the autumn when they are sent to market.

Any contributions of faecal contamination from livestock kept on farms located along the southeast shore of the loch would be most likely to affect the mussel farm at An Druim, whilst livestock kept on crofts at Laid would be most likely to affect the Laid mussel farm. The area of trestles was north of the recorded livestock locations, however it was adjacent to crofted areas and therefore it is possible that animals may be grazed there at other times, during which there would be an impact at the trestles.



Produced by Cefas Weymouth Laboratory.

Figure 5.1 Livestock observations at Loch Eriboll

6. Wildlife

Pinnipeds

The grey seal (*Halichoerus grypus*) is found in large numbers in Loch Eriboll. There are no accounts of any common/harbour seal populations. Whiten Head, which lies at the entrance of Loch Eriboll, represents the largest mainland breeding colony of grey seals in the UK (Highland Council Planning and Development Service, 2000) Grey seals use the sheltered sea caves to rear pups between October and February (Scottish Natural Heritage, 2013). It is expected that seals from this colony will use Loch Eriboll to forage and shelter from rough weather from time to time. No seals were observed at the time of the shoreline survey.

Cetaceans

Loch Eriboll is not a key habitat for any cetacean species, though there are accounts of both the common dolphin (*Delphinus delphis*) and the harbour porpoise (*Phocoena phocoena*) in Loch Eriboll (Assynt Field Club, 2013). There are also official accounts reported by the British Divers Marine Life Rescue (BDMLR) on the stranding of both harbour porpoise and Atlantic white sided dolphin (British Divers Marine Life Rescue, 2011) within Loch Eriboll. No cetaceans were observed during the shoreline survey. The area surrounding Loch Eriboll is important for many different cetacean species, including killer whales that hunt the grey seals that form a colony at the mouth of Loch Eriboll.

Birds

Seabird 2000 census data (Mitchell, et al., 2004) was queried for the area within a 5 km radius of the Loch Eriboll production area and the output is summarised in Table 6.1 and displayed in Figure 6.1. This census was undertaken between 1998 and 2002 and covered the 25 species of seabird that breed regularly in Britain and Ireland.

Table 6.1 Seabird counts within 5 km of Loch Eriboll.

Common name	Species	Count*	Method
Black guillemot	*Cepphus grylle*	26	Individuals on land
European Herring Gull	*Larus argentatus*	20	Occupied nests
Lesser Black-backed Gull	*Larus fuscus*	66	Occupied nests
Great Black-backed Gull	*Larus marinus*	132	Occupied nests
Northern Fulmar	*Fulmarus glacialis*	314	Occupied sites
European Shag	*Phalacrocorax aristotelis*	8	Occupied nests

*Occupied nest sites have been multiplied by two.

The mouth of Loch Eriboll is an important nesting area for several species of seabird. Eilean Hoan, an island NW of the mouth of Loch Eriboll, is a designated SSSI for

Greenland barnacle geese. Although this area has high numbers of birds, it is located >7 km north of the fisheries in Loch Eriboll.

Closer to the fishery, Eilean Choraidh hosts nesting colonies of three species of gull and would be a significant potential source of faecal contamination during the breeding season (May-August). It is anticipated that faecal contamination from this area will be greatest at and following the breeding season, and due to its close location to the Laid site (<1 km northeast) it is likely that it will be a significant source of faecal contamination at that time.

Other birds also present in Loch Eriboll include the great northern divers which use Loch Eriboll as a winter/spring refuge, with up to 45 individuals present at this time. Significant numbers of red-throated divers, black-throated divers and Slavonian grebes are also present during the winter months. Large flocks of eider duck are also common, and are known to rest on the mussel longlines in Loch Eriboll (Highland Council Planning and Development Service, 2000).

Birds were the only wildlife observed during the survey and were seen along the east, west and southern shorelines. Species observed included; red-throated divers, oystercatchers, the common sandpiper and eider ducks, with oyster catchers being the most prevalent. Observations only apply to the time of this survey and spatial distribution is likely to vary.

Deer

The moorland surrounding Loch Eriboll represents ideal habitat for Red and Roe deer. Although no population data was available on deer around Loch Eriboll, many anecdotal accounts of deer were found during an internet search (Guardian, 2011). No deer were observed during the shoreline survey. However, the sampling officer reported having often seen red deer, mainly on the east shore of the loch.

Otters

The Eurasian otter (*Lutra lutra*) is stated as present in Loch Eriboll (Highland Council Planning and Development Service, 2000), though there are no population estimates for the area. To the east of Loch Eriboll, the Caithness and Sutherland Peatlands SAC is designated for otters. This SAC boundary stops about 20 km from Loch Eriboll, though it is likely that the habitat surrounding Loch Eriboll will be similar, and thus suitable to support colonies of otters. No otters were observed during the shoreline survey. However, the sampling officer reported seeing otters at the RMP.

Overall

Wildlife are likely to contribute a significant proportion of any faecal contamination found in Loch Eriboll. Only those likely to be present near or on the fisheries are likely to contribute to *E. coli* in the shellfish there. Greatest impacts are likely to be from ducks and gulls feeding or resting on the shellfish farms and from the breeding colony of gulls present on Eilean Choraidh. Impacts from seals are most likely around the northern end of the loch.

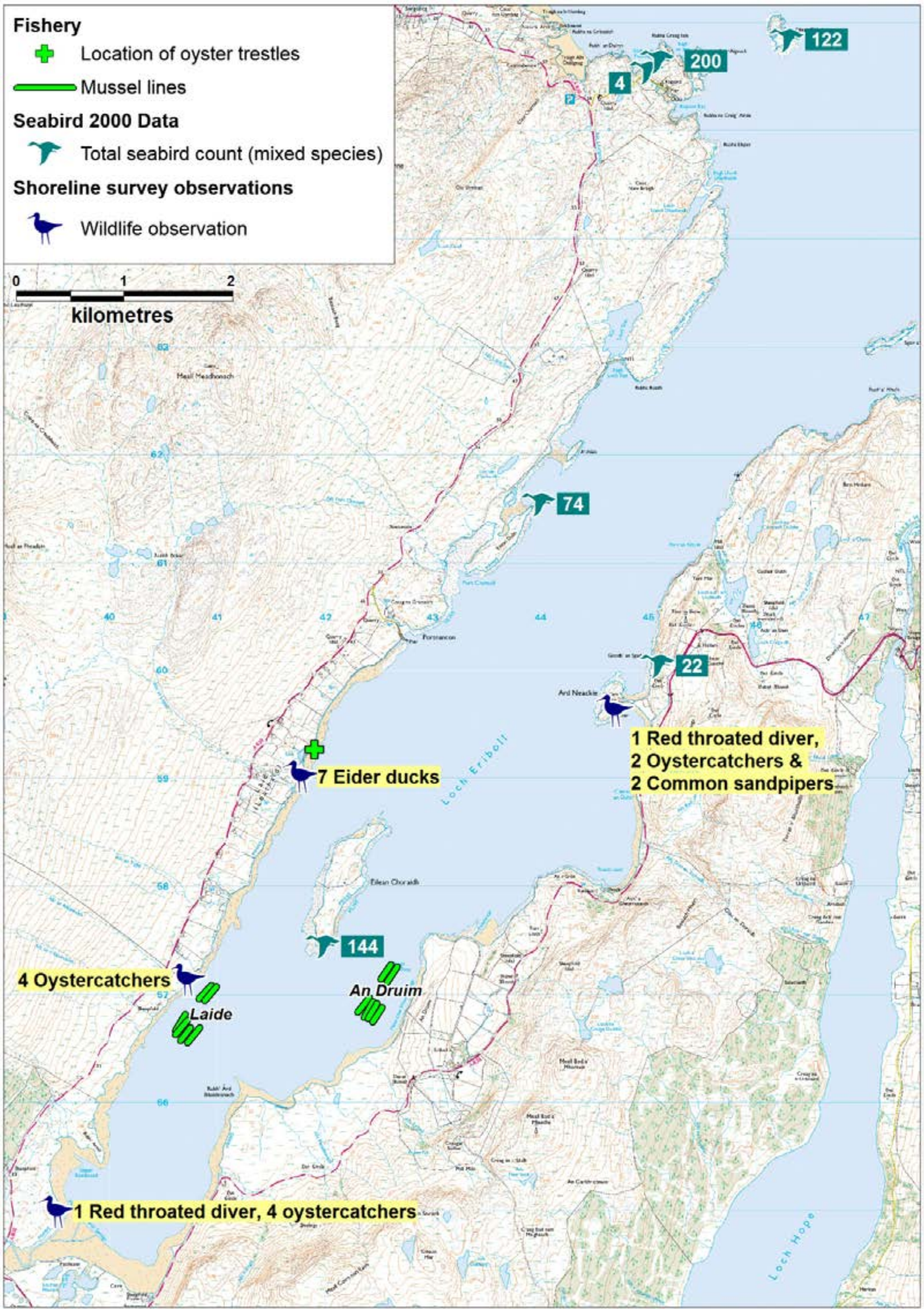


Figure 6.1 Map of wildlife around Loch Eriboll

7. Land Cover

The Land Cover Map 2007 data for the area is shown in Figure 7.1 below:

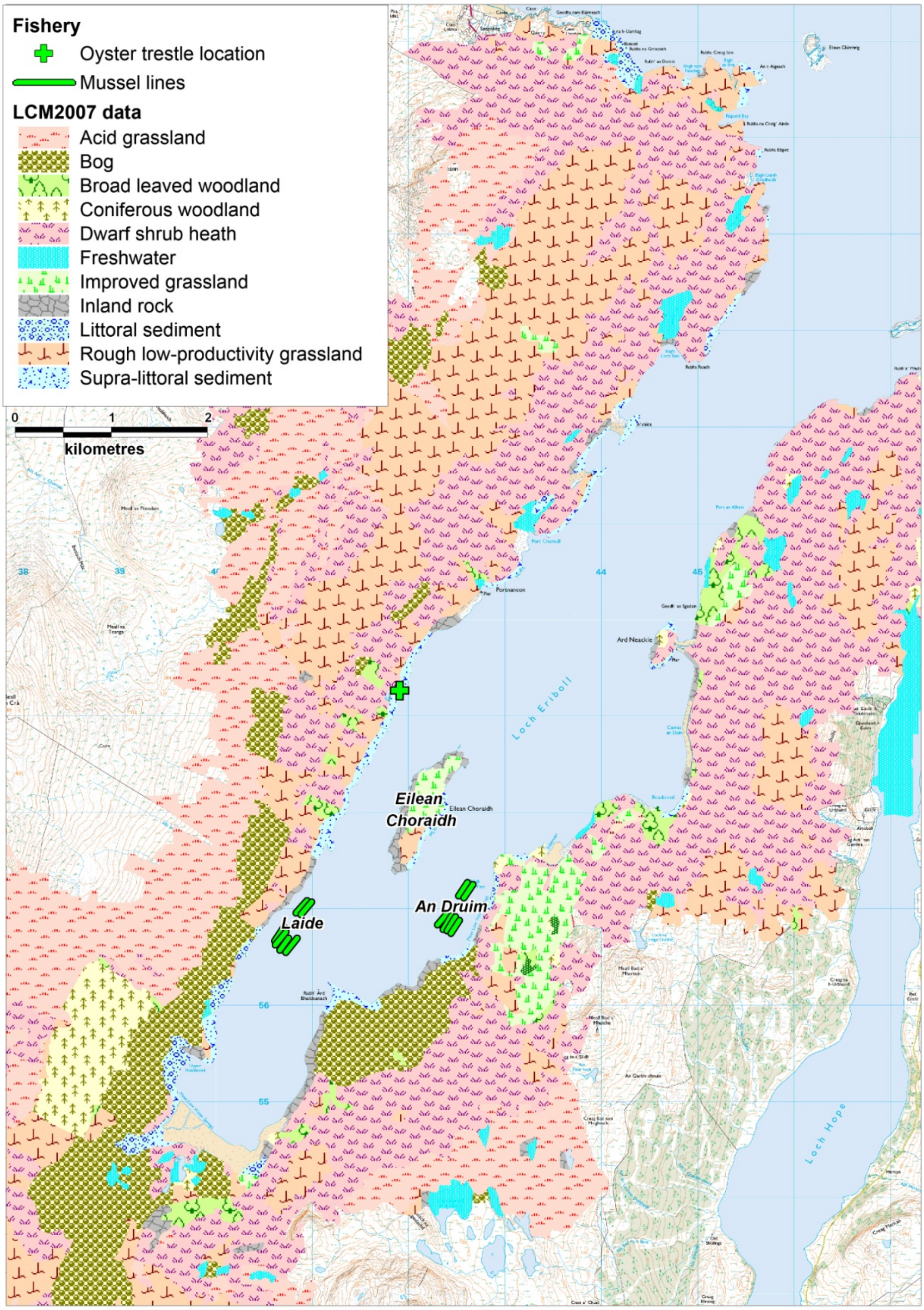


Figure 7.1 LCM2007 class land cover data for Loch Eriboll

The tiles purchased from the LandCover 2007 data covered the entire shoreline of Loch Eriboll, but did not extend uniformly inland to cover all areas shown in Figure 7.1. Dwarf shrub heath, bog, acid grassland and rough grassland are the predominant land cover types on the coastline surrounding Loch Eriboll. There are also smaller areas of improved grassland and coniferous and broad-leaved woodland. There are no areas of suburban or urban development. The improved grassland can be found on Eilean Choraidh and opposite this island on the eastern shoreline. The SEPA Loch Eriboll Growing Waters report (2011) confirmed that the land cover in the area is predominantly a mixture of bog and heather moorland.

Faecal indicator organism export coefficients for faecal coliform bacteria have been found to be approximately 8.3×10^{8} cfu km^{-2} hr^{-1} for areas of improved grassland and approximately 2.5×10^{8} cfu km^{-2} hr^{-1} 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 Eriboll fishery would be from the areas of improved grassland on the east shore north of An Druim and on the northern end of Eilean Choraidh. Land utilised for rough grazing would be expected to contribute significantly to faecal contaminant loading carried in watercourses and overland flow draining those areas during rainfall.

8. Watercourses

There are no gauging stations on watercourses entering into Loch Eriboll. The Sea Loch Catalogue(Edwards & Sharples, 1986) reports that freshwater input to Loch Eriboll is at 134.0 M m^3/ year, with an average annual rainfall of 1500 mm, indicating freshwater input is moderate. The largest watercourse discharging to Loch Eriboll is the River Hope, which lies approximately 7km northeast of the trestle area and outwith the area surveyed.

The shoreline survey was conducted between the 8th and 10th April 2013. No precipitation fell in the 48 hrs preceding the survey, and it was noted that in the two months prior to the survey, little rainfall had fallen in the area. No rainfall fell on the first day of surveying, but on the second and third day, hail showers were recorded.

All freshwater samples returned *E. coli* results below the limit of detection (<100 *E. coli* CFU/ 100 ml). Loadings were therefore not calculated. Table 8.1 below lists the major freshwater inputs into Loch Eriboll at the time of the survey, with location displayed in Figure 8.1.

Table 8.1 Watercourses discharging to Loch Eriboll

No	NGR	Description	Width (m)	Depth (m)	Flow (m^3/d)
1	NC 4344 5743	Stream	1.2	0.15	560
2	NC 4236 5641	Allt Eriboll	1.1	0.05	520
3	NC 4183 5612	Allt Meadhonach	0.6	0.05	600
4	NC 4171 5598	Stream	1.7	0.09	650
5	NC 4103 5535	Allt h-Eisgil	1.5	0.13	2400
6	NC 4037 5417	Stream	2.0	0.20	310
7	NC 3900 5474	Amhainn an t-Stratha Bhig	8.4	0.24	35500
8	NC 3950 5565	Stream	2.9	0.18	1900
9	NC 3985 5588	Stream	2.1	0.19	650
10	NC 4098 5753	Stream	0.7	0.31	260
11	NC 4109 5783	Allt a Tighe	1.2	0.10	320
12	NC 4113 5792	Stream	1.6	0.07	19
13	NC 4170 5892	Allt an Lagain	2.6	0.28	1300
14	NC 4268 6044	Allt Portnancon	2.2	0.14	830
15	NC 4313 6095	Allt Port Chamuill	1.2	0.13	1300

Due to there being a very dry spell in the two months prior to this survey, five of the watercourses noted on the OS map were not flowing when encountered on the survey. Measurements and samples could therefore not be taken. The locations of these dry watercourses have been included in Figure 8.1.

Watercourses enter Loch Eriboll along much of the area surveyed, though the three largest of these were located nearer to the head of the loch. Within the area surveyed, the largest freshwater input was Amhainn an t-Stratha Bhig, which enters at the head of Loch Eriboll. After significant rainfall, higher flows and E. coli levels would be normally be expected in streams, though it is not possible to predict what these might be.

In general, the watercourses most likely to contribute faecal contamination would be those:

- With highest flow
- Located nearest the fishery

The high- flow watercourses located near the head of the loch have the potential to impact water quality in the southern end of the loch, with any impact likely to occur first along the southern ends of the mussel lines at Laid. The An Druim site is more likely to be affected by the cluster of watercourses located within 1 km to the southwest of the mussel farm. A further watercourse that passes through pasture and adjacent to properties discharges approximately 1 km northeast of the north end of the An Druim site.

The trestle area would be most affected by the Allt an Lagain and any outflow from the small, spring-fed loch south of the trestles. Any contamination arising from these would impact the southern extent of the trestles first.

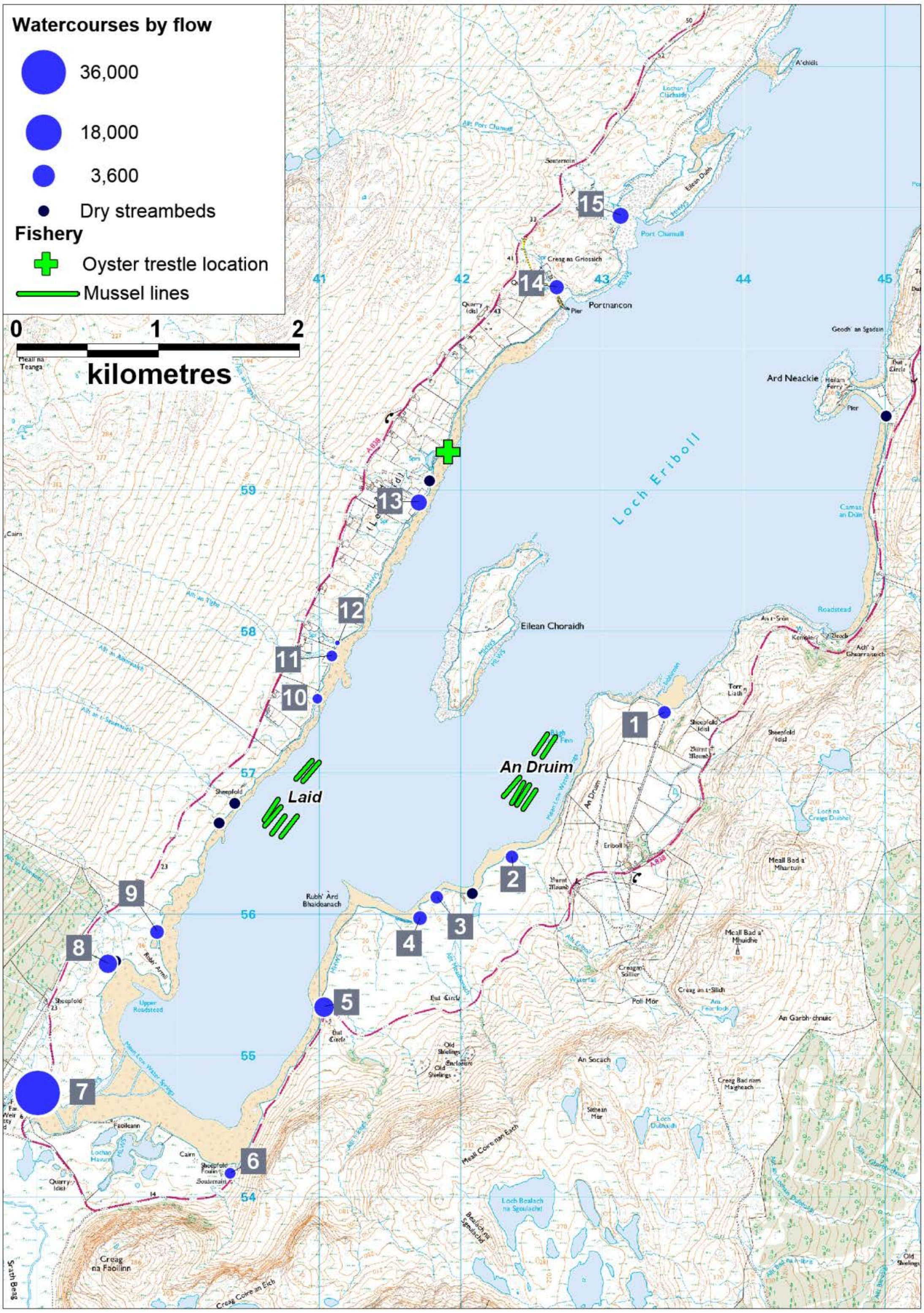


Figure 8.1 Map of watercourse loadings at Loch Eriboll

9. Meteorological Data

The nearest weather station for which a nearly complete rainfall data set was available is located at Achfary, situated approximately 18 km to the south west of the production area. Rainfall data was obtained for this station for the period 1 January 2007 to 31 December 2012. The nearest wind station is situated in Wick Airport, located 91 km east 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 UK 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 Eriboll.

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 *.

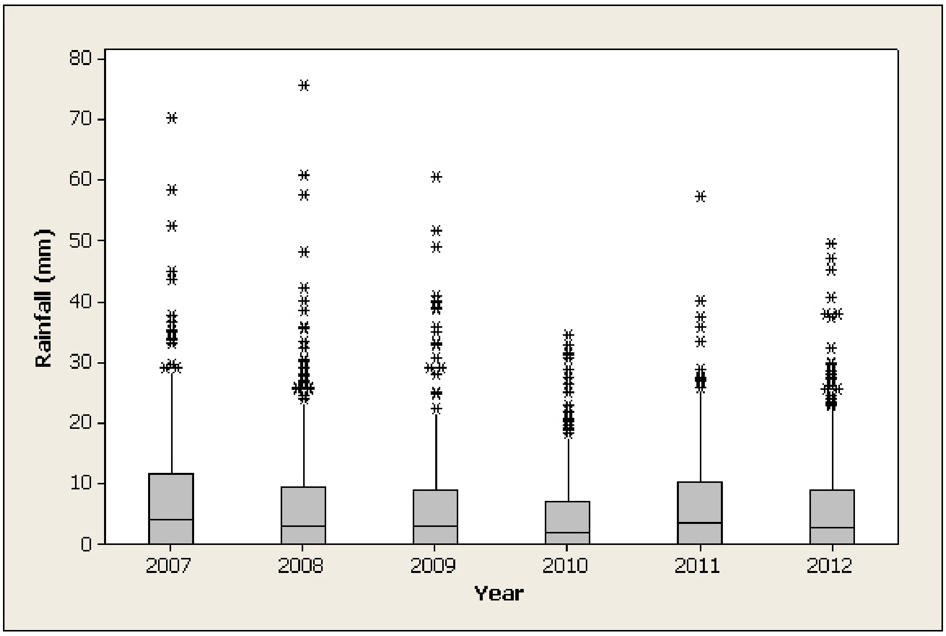


Figure 9.1 Box plot of daily rainfall values by year at Achfary (2007 – 2012)

Daily rainfall values varied from year to year, with 2007 being wettest and 2010 being driest. Rainfall events in excess of 30 mm/day occurred in all years. Rainfall of greater than 70 mm/day was recorded on two occasions, in 2007 and 2008.

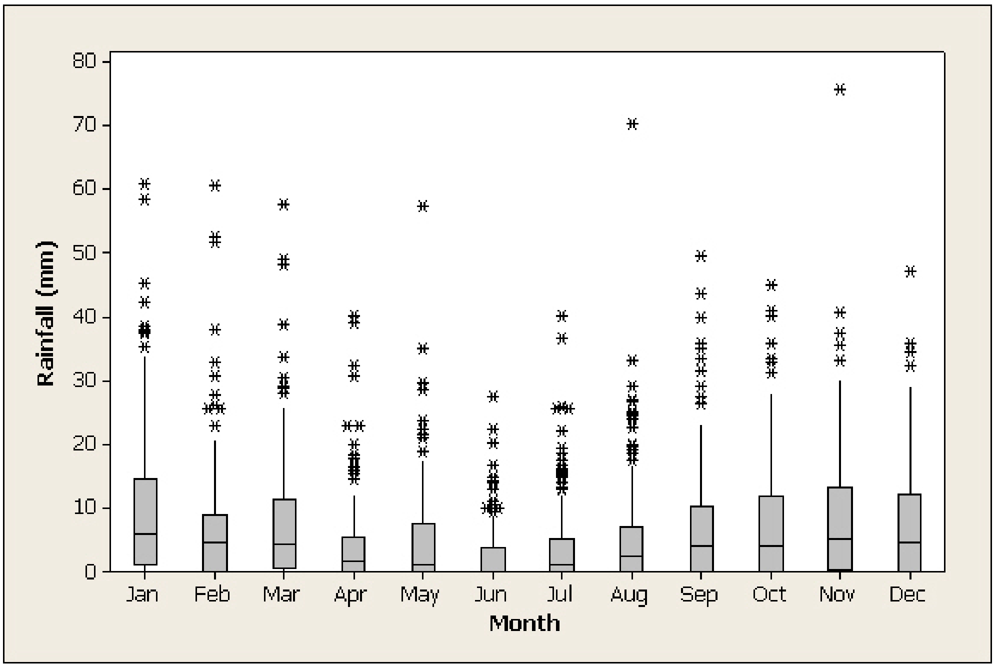


Figure 9.2 Box plot of daily rainfall values by month at Achfary (2007 – 2012)

Daily rainfall values were higher during the autumn and winter. Rainfall increased from September onward and was highest in January and November. Weather was drier from April to August. Rainfall values exceeding 30 mm/d occurred in all months except June. The most extreme events occurred in August and November.

For the period considered here (2007 – 2012) 40 % of days received daily rainfall of less than 1 mm and 18 % of days received rainfall of over 10 mm.

Run-off due to rainfall is expected to be higher during the autumn and winter months. However, extreme rainfall events leading to episodes of high run-off can occur in most months and when these occur during generally drier periods in summer and early autumn, 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 Wick Airport and summarised in seasonal wind roses in Figure 9.3 and annually in Figure 9.4.

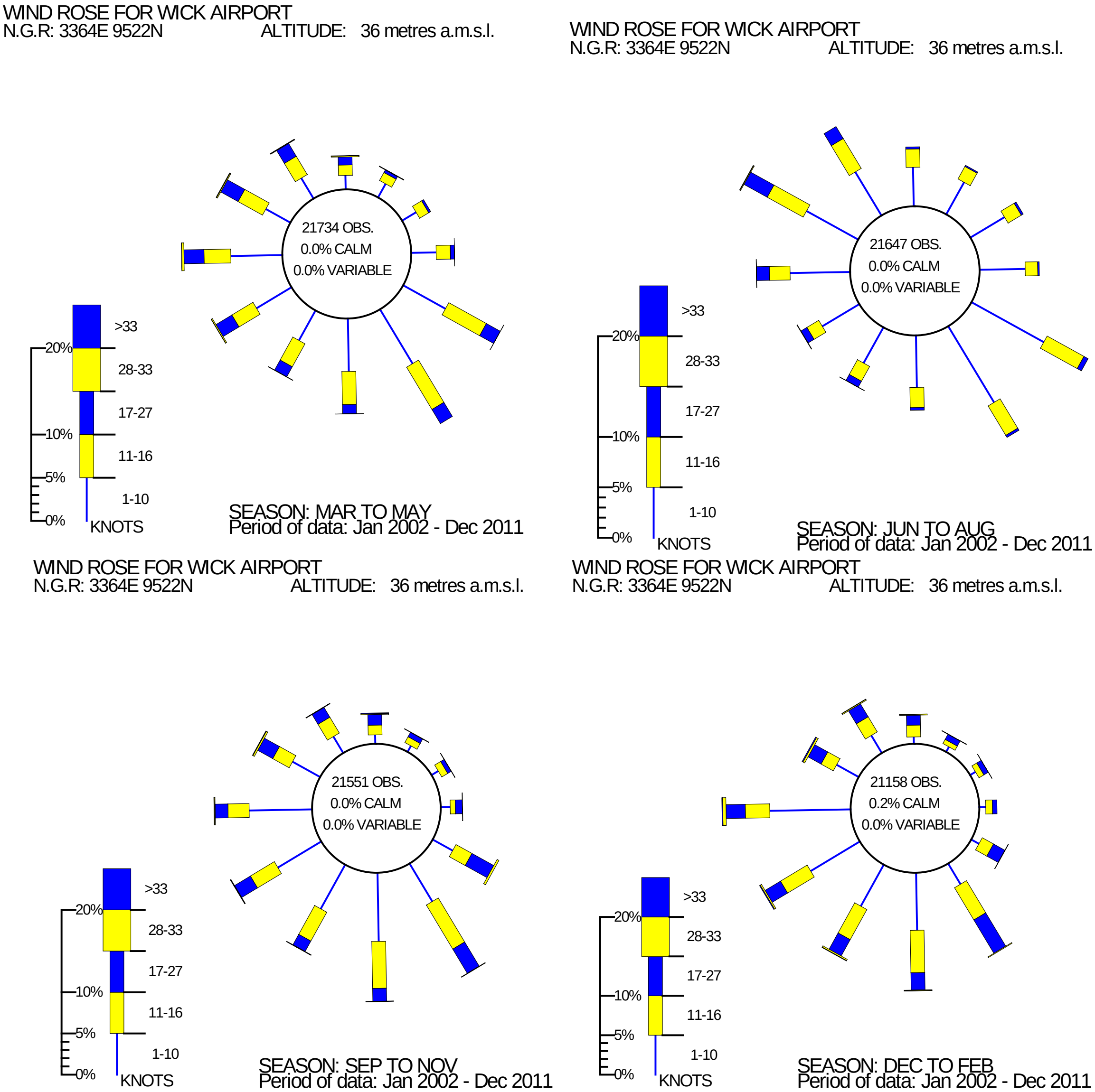


Figure reproduced under license from Meteorological Office. Crown Copyright 2012.

Figure 9.3 Seasonal wind roses for Wick Airport

Winds varied markedly between seasons, with winds from the southeast generally predominating. The predominant wind direction observed at Wick may be influenced by the fact the estuary in which this lies faces to the southeast. Winds from the northwest were more frequent from June to August and from the west noticeably more frequently from December to February. Winds from the east and northeast occurred more frequently from June to August, but were also lighter during these months than during the rest of the year.

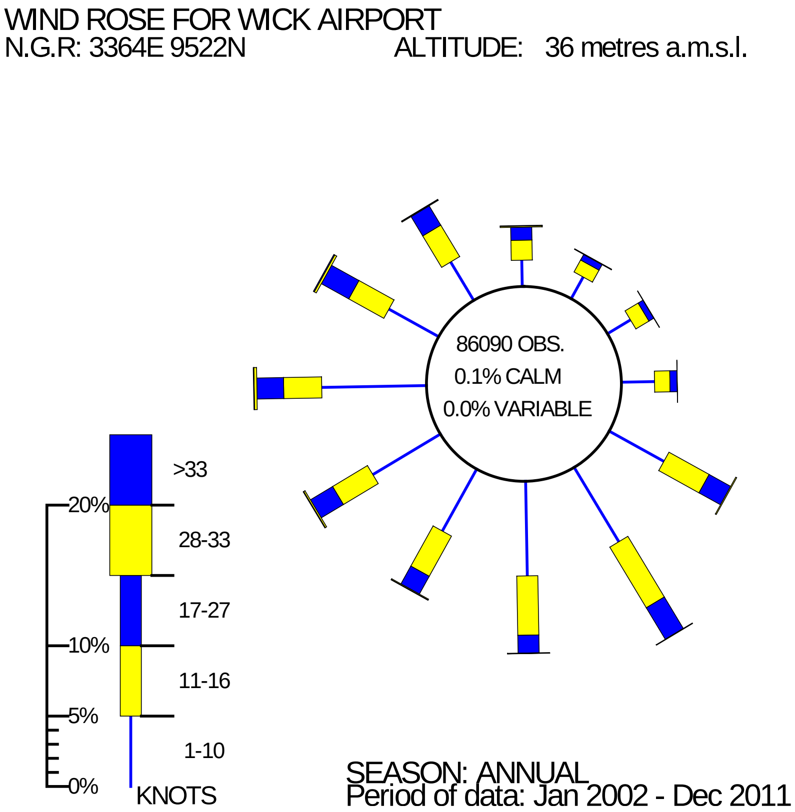


Figure 9.4 Annual wind rose for Wick Airport

Overall the annual wind rose shows that winds are very rarely calm at this station. Strongest winds blow from the west, though the prevailing winds generally blow from the southeast.

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

The area has been classified for both common mussel and Pacific oyster production since 2001. The classification history since 2006 is listed in Table 10.1 for the common mussel classification history and Table 10.2 for the Pacific oyster classification history.

Table 10.1 Loch Eriboll (Common Mussels) 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	B	B	B	B	A	A
2009	A	A	A	A	A	A	B	B	B	B	A	A
2010	A	A	A	A	A	A	A	A	A	A	A	A
2011	A	A	A	A	A	A	B	B	B	B	A	A
2012	A	A	A	A	A	A	A	A	A	B	B	B
2013	A	A	A									
2014												

The site is currently a seasonal A/B mix with the B classified months occurring late autumn and early winter. This is in contrast to previous years when B months occurred from late summer to early autumn.

Table 10.2 Loch Eriboll (Pacific oysters) 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									
2014												

The site has held year round A classification for Pacific oysters during the entire period considered above.

11. Historical *E. coli* Data

11.1 Validation of historical data

Results for all samples assigned against the two common mussels sites (MacLennan and Loch Eriboll) and the two Pacific oyster sites (MacLennan and Loch Eriboll) within the Loch Eriboll production area for the period between 01/01/2008 to the 10/05/2013 were extracted from the FSAS database in May 2013 and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. All *E. coli* results were reported as most probable number (MPN) per 100 g of shellfish flesh and intravalvular fluid. All sample results reported as <20 *E. coli MPN*/100 g were reassigned a value of 10 *E. coli MPN*/100 g for the purposes of statistical evaluation and graphical representation.

For the purposes of statistical analysis, results from the two Pacific oyster sites have been combined, and results from the two common mussel sites have been combined.

One common mussel sample [CEFAS_13/025] was recorded as rejected and was excluded from the assessment. Three samples were geographically outwith Loch Eriboll and were excluded; one sample plotted 15 m inland and two plotted 17 km southeast in the adjacent Kyle of Tongue production area. All other samples arrived within the allowed 48 hr window between sample collection and delivery, with all samples having a box temperature of <8°C. Twenty eight samples had results of <20 *E. coli* MPN/ 100 g.

Four Pacific oyster samples were recorded in the database as rejected and were excluded from the assessment. Three samples were geographically outwith Loch Eriboll and were excluded: one plotted 6.3 km east inland and two samples plotted 17 km southeast in the adjacent Kyle of Tongue production area. All samples arrived within the allowed 48 hr window between sample collection and delivery, with all samples having a box temperature of <8°C. Thirty-seven samples had *E. coli* results of <20 *E. coli* MPN/ 100 g.

11.2 Summary of microbiological results

Table 11.1 Summary of historical sampling and results for Loch Eriboll

Sampling Summary		
Production area	Loch Eriboll	
Site	Loch Eriboll & MacLennan	Loch Eriboll & MacLennan
Species	Common mussels	Pacific oysters
SIN	HS-139-305-08 & HS-139-307-08	HS-139-305-13 & HS-139-307-13
Location	Various	Various
Total no of samples	44	49
No. 2008	7	7
No. 2009	5	6
No. 2010	8	10
No. 2011	11	10
No. 2012	11	12
No. 2013	3	4
Results Summary		
Minimum	<20	<20
Maximum	1300	330
Median	<20	<20
Geometric mean	23	15
90 percentile	370	50
95 percentile	700	150
No. exceeding 230/100g	5 (11%)	1 (2%)
No. exceeding 1000/100g	1 (2%)	0 (0%)
No. exceeding 4600/100g	0 (0%)	0 (0%)
No. exceeding 18000/100g	0 (0%)	0 (0%)

Sampling results for the two common mussel sites and the two Pacific oyster sites have been combined in Table 11.1.

Sampling of common mussels has varied across years, with between 5 to 11 samples taken each year since 2008. Sampling became more regular from 2010. Results varied between <20 – 1300 *E. coli* MPN/ 100 g, with many results <20 as shown by the median.

Sampling of Pacific oysters has similarly varied across years, with sampling also become more regular since 2010. Forty-nine samples have been taken in total. The majority of results were <20 *E. coli* MPN/ 100 g and only one sample exceeded 230 *E. coli* MPN/ 100 g.

11.3 Overall geographical pattern of results

The geographical locations of sample results for the common mussels and Pacific oysters are shown in Figures 11.1 and 11.2 respectively. Samples for both species have generally been taken in the vicinity of the RMP.

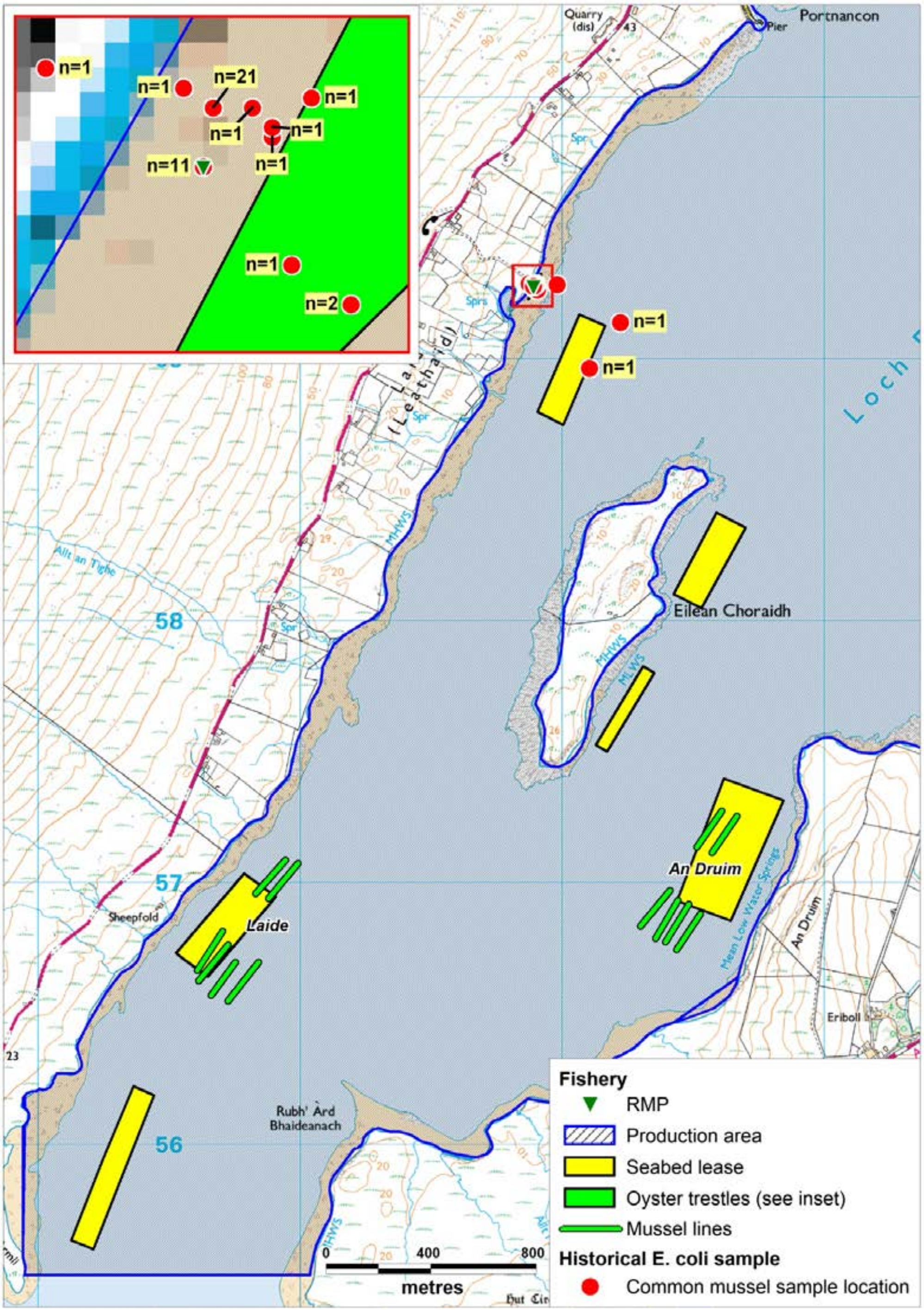


Figure 11.1 Map of Loch Eriboll common mussel sampling result locations

Two common mussel samples appear to have been taken at the mussel lines, offshore from the RMP. Both were taken in 2008 at returned results of <20 and 20 *E. coli* MPN/ 100 g. One other result lay outside the main collection of samples, just below mean low water springs, and was taken in 2011. This sample returned a result of 20 *E. coli* MPN/ 100 g. The remaining 42 samples were all taken within 20 m of the RMP, though no clear trend in results was seen. Two areas were sampled repeatedly: at NC 4189 5928 (the RMP) and at NC 4189 5929.

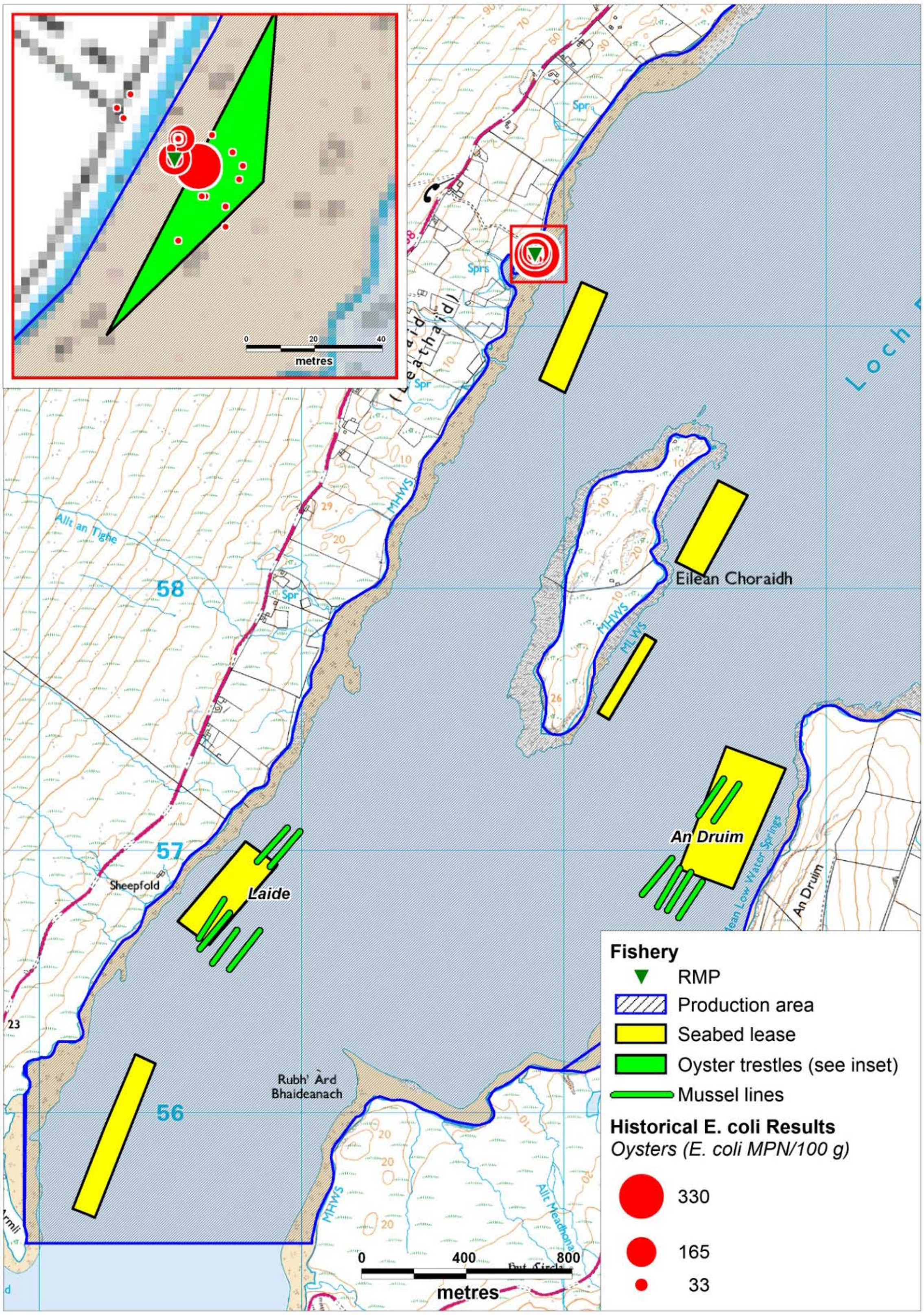


Figure 11.2 Map of Loch Eriboll Pacific oyster sampling result locations

The Pacific oyster samples were been taken from the area of trestles identified during the shoreline survey. Results all plotted within 20 m of the RMP at NC 4189 5928. High results tended to occur in samples taken from locations higher up the shore, close to the RMP, however it is not clear whether this is truly a spatial trend or simply due to the fact that most samples came from the RMP.

11.4 Overall temporal pattern of results

Scatterplots of individual species *E. coli* results against date are presented in Figures 11.3 and 11.4. The datasets are fitted with a lowess trend line. Lowess trendlines allow for locally weighted regression scatter plot smoothing. At each point in the dataset an estimated value is fitted to a subset of the data, using weighted least squares. The approach gives more weight to points near to the x-value where the estimate is being made and less weight to points further away. In terms of the monitoring data, this means that any point on the lowess line is influenced more by the data close to it (in time) and less by the data further away. The trend line helps to highlight any apparent underlying trends or cycles.

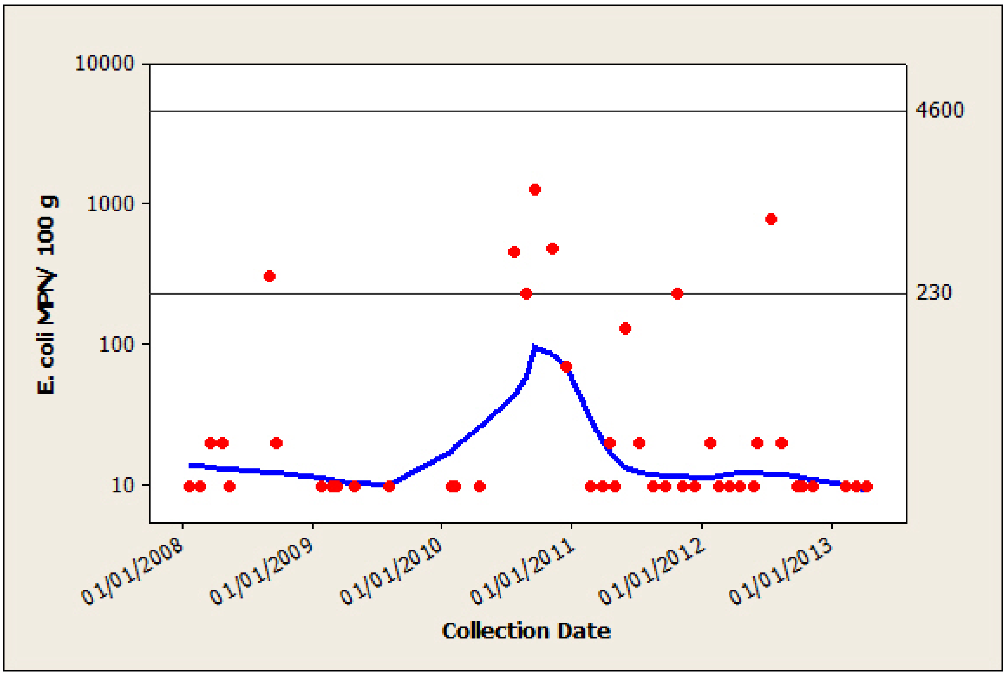


Figure 11.3 Scatterplot of common mussel *E. coli* results by date with a lowess line

Contamination levels in common mussel samples appear predominantly low across sampling years 2008-2013, with the majority of results <20 *E. coli* MPN/ 100 g. A peak in results occurs in 2010 when 3 of 7 results were >230 *E. coli* MPN/ 100 g.

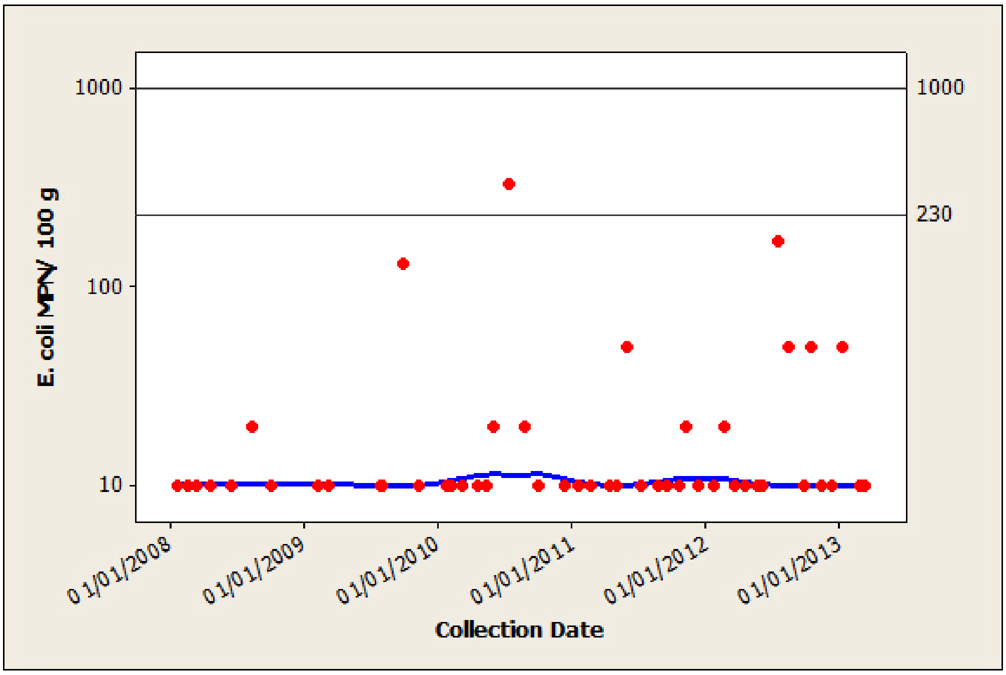


Figure 11.4 Scatterplot of Pacific oyster *E. coli* results by date with a lowess line

Contamination levels in Pacific oyster samples were low throughout sampling years 2008-2013, with the majority of results <20 *E. coli* MPN/ 100 g.

11.5 Seasonal pattern of results

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns in human distribution. All of these can affect levels of microbial contamination, causing seasonal patterns in results. Scatterplots of individual species *E. coli* results by month, overlaid with lowess lines are found in Figures 11.5 and 11.6. Jittering was applied at 0.01 (x-axis) and 0.001 (y-axis) for the oysters and 0.02 (x-axis) and 0.001 (y-axis) for the mussels.

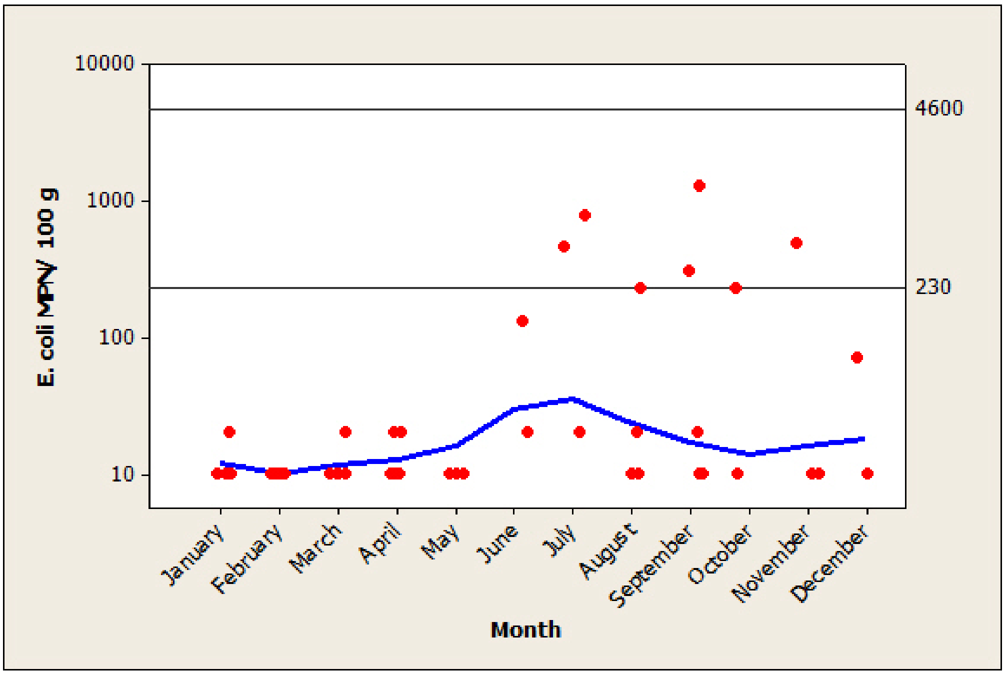


Figure 11.5 Scatterplot of common mussel *E. coli* results by month, fitted with a lowess line

Highest results in common mussels (>230 *E. coli* MPN/ 100 g) occurred between July and November, with the highest in September. Sampling across months was variable, with between 2 and 6 samples taken in each month. However, at least three samples were taken in all months except June, October and December, when only two samples were taken.

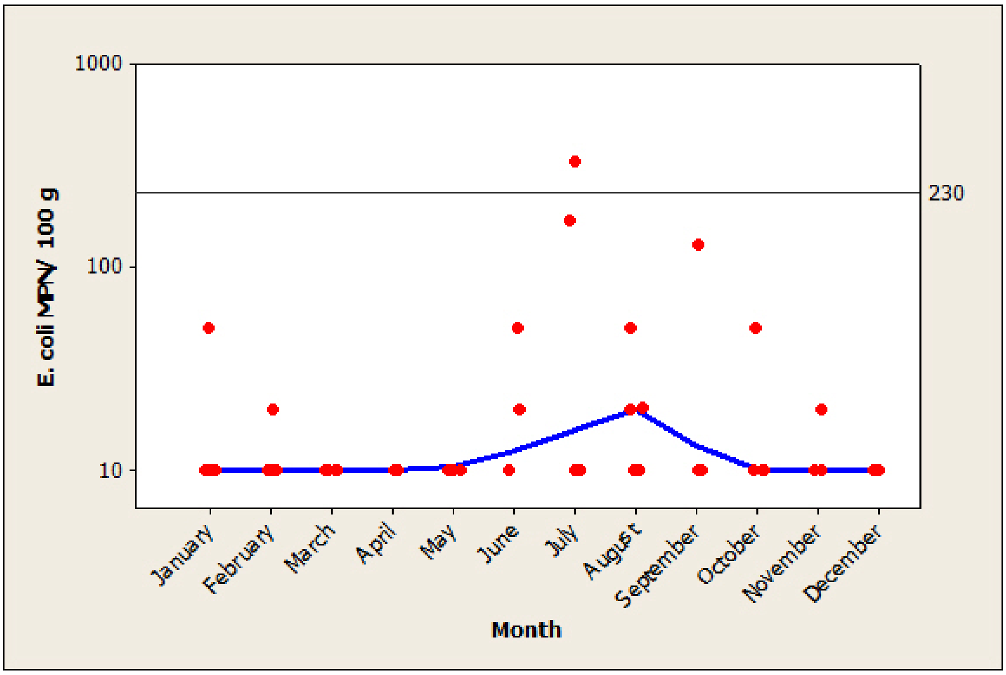


Figure 11.6 Scatterplot of Pacific oyster *E. coli* results by month, fitted with a lowess line

The highest result in Pacific oysters (230 *E. coli* MPN/ 100 g) occurred in July. Sampling varied, with between 3 and 6 samples taken in each month.

For statistical evaluation, seasons were split into spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). Boxplots of individual species *E. coli* results by season are presented in Figures 11.7 and 11.8.

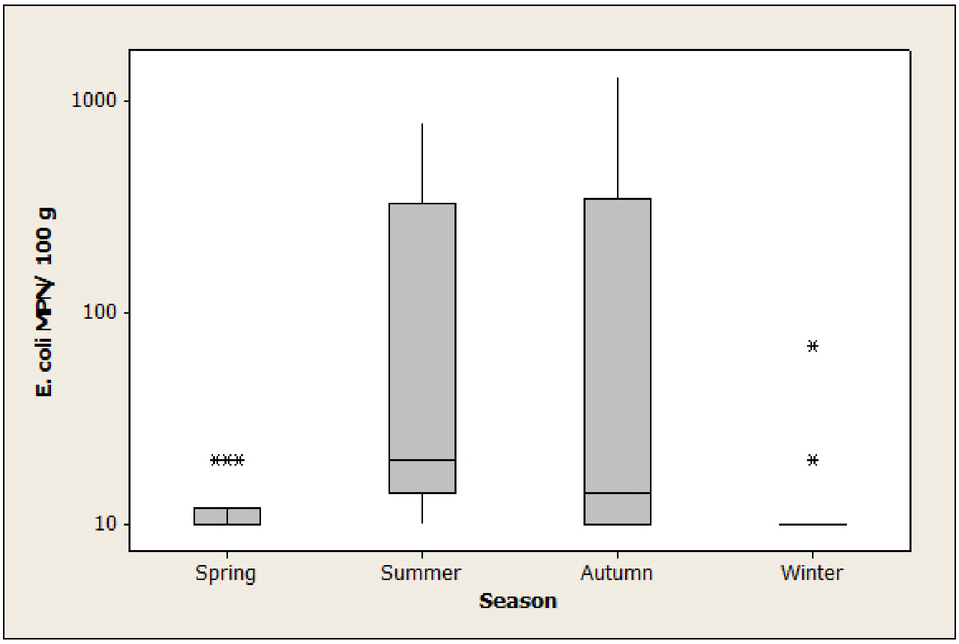


Figure 11.7 Boxplot of common mussel *E. coli* results by season

A statistically significant difference was found between common mussel results by season (one-way ANOVA, F = 5.39, p = 0.003, Appendix 4). Results in summer and autumn were higher than those in spring, whilst results in winter were lower than those in summer.

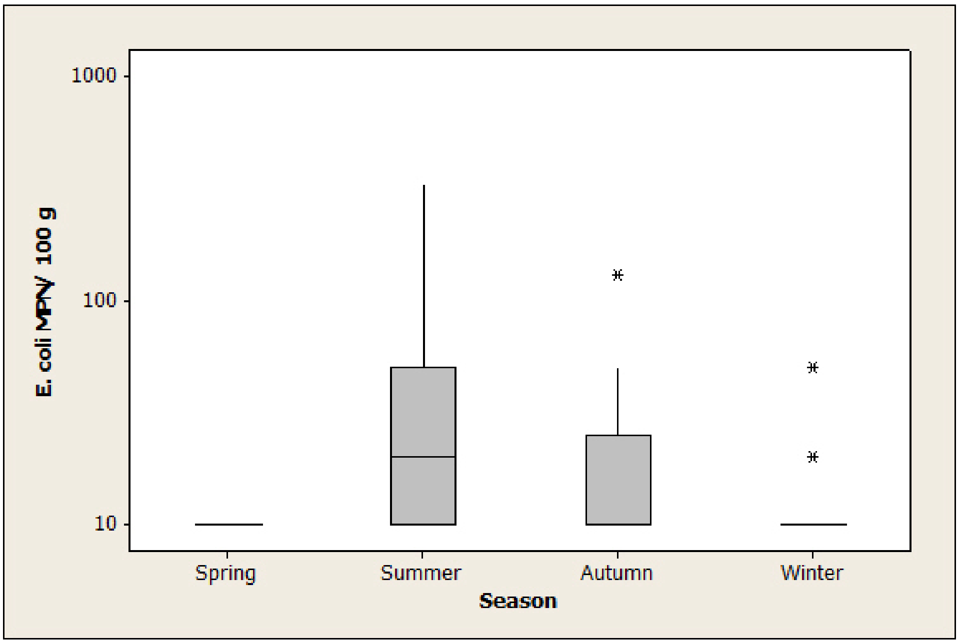


Figure 11.8 Boxplot of Pacific oyster *E. coli* results by season

A statistically significant difference was found in Pacific oyster sample results by season (one-way ANOVA, F = 3.37, p = 0.027, Appendix 4). Results in summer were higher than those in spring.

11.6 Analysis of results against environmental factors

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

11.6.1 Analysis of results by recent rainfall

The nearest weather station with available rainfall data was at Achfary, approximately 5 km N-NW of the production area. Rainfall data was purchased from the Meteorological Office for the period of 01/01/2008 to 31/12/2012 (total daily rainfall in mm). Data was extracted from this for common mussels between 01/01/2008 until 31/12/2012.

Two-day antecedent rainfall

Scatterplots present individual species *E. coli* results against total rainfall recorded on the two days prior to sampling in Figures 11.9 and 11.10. Rainfall was recorded 44/48 common mussel samples and for 48/52 of the Pacific oyster samples. Jittering was applied to individual results from common mussel and Pacific oyster samples at 0.01 and 0.001 on the X and Y axis respectively.

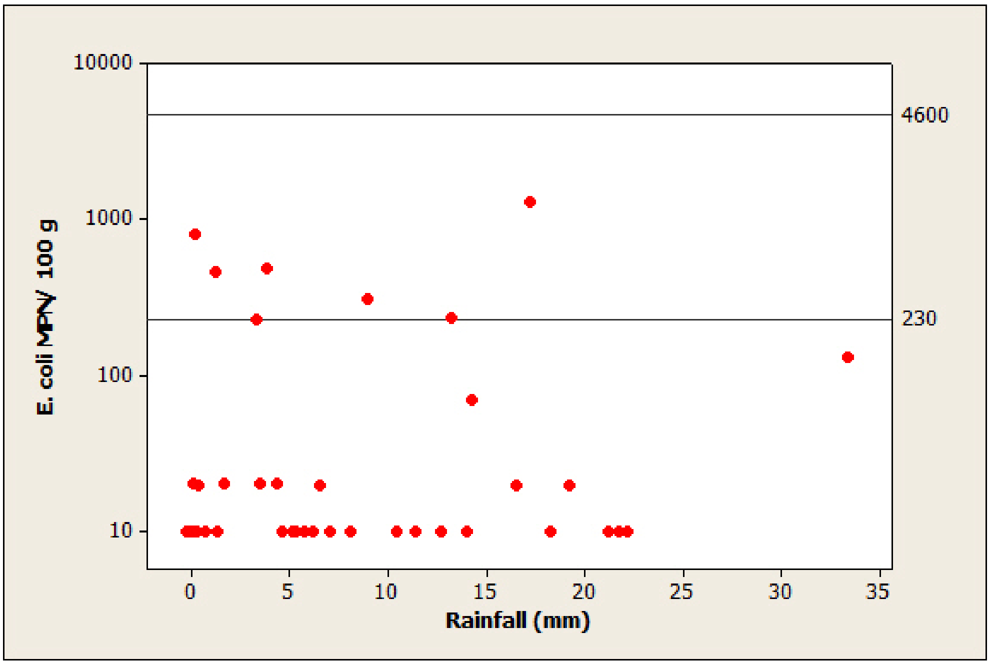


Figure 11.9 Scatterplot of common mussel *E. coli* results against rainfall in the previous two days

No significant correlation was found between common mussel sample results and the previous two day rainfall (Spearman's rank correlation r = 0.061, p = 0.706).

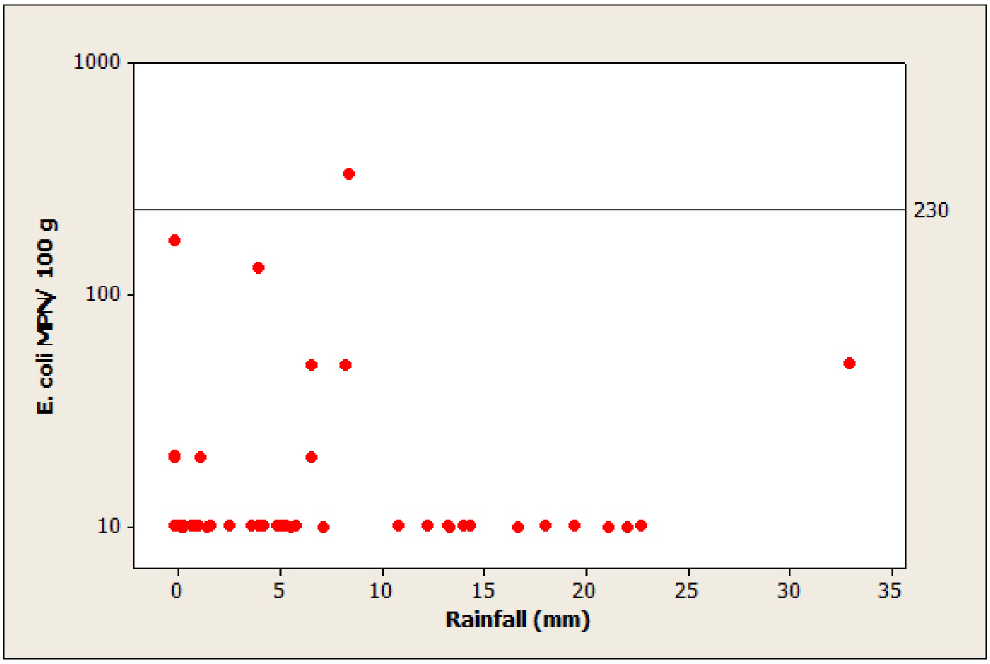


Figure 11.10 Scatterplot of Pacific oyster *E. coli* results against rainfall in the previous two days

No significant correlation was found between Pacific oyster results and 2-day rainfall (Spearman's rank correlation r = -0.028, p = 0.857).

Seven-day antecedent 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. Scatterplots present individual species *E. coli* results against total rainfall recorded for the seven days prior to sampling in Figures 11.11 and 11.12. Jittering was applied to individual results for both common mussel and Pacific oyster samples at 0.01 and 0.001 on the X and Y axis respectively.

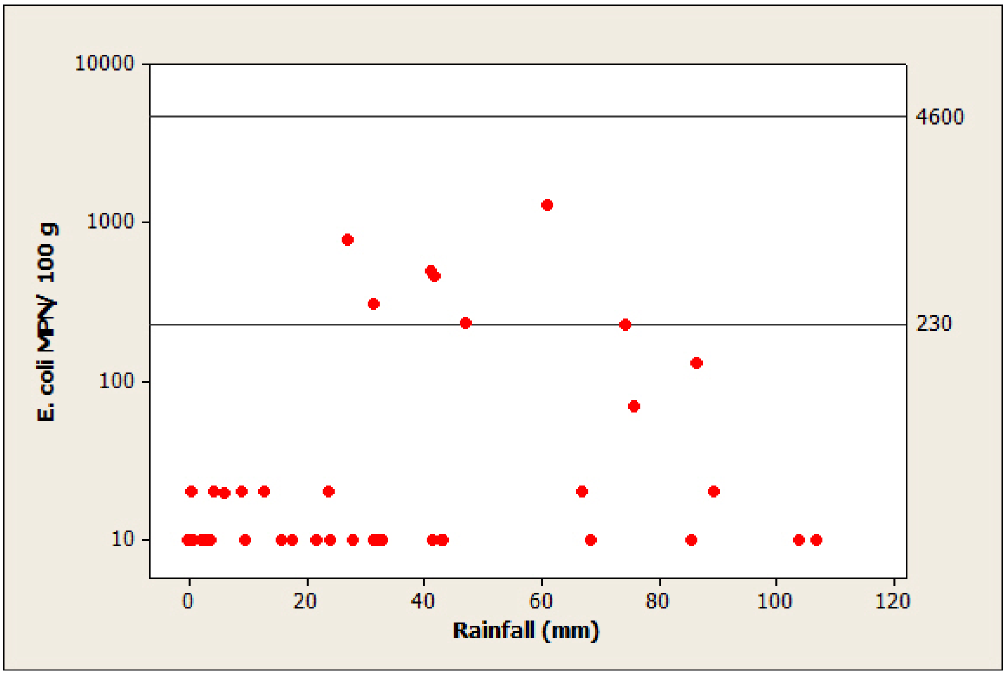


Figure 11.11 Scatterplot of common mussel *E. coli* results against rainfall in the previous seven days

No significant correlation was found between common mussel results and 7-day rainfall. (Spearman's rank correlation r = 0.261, p = 0.099).

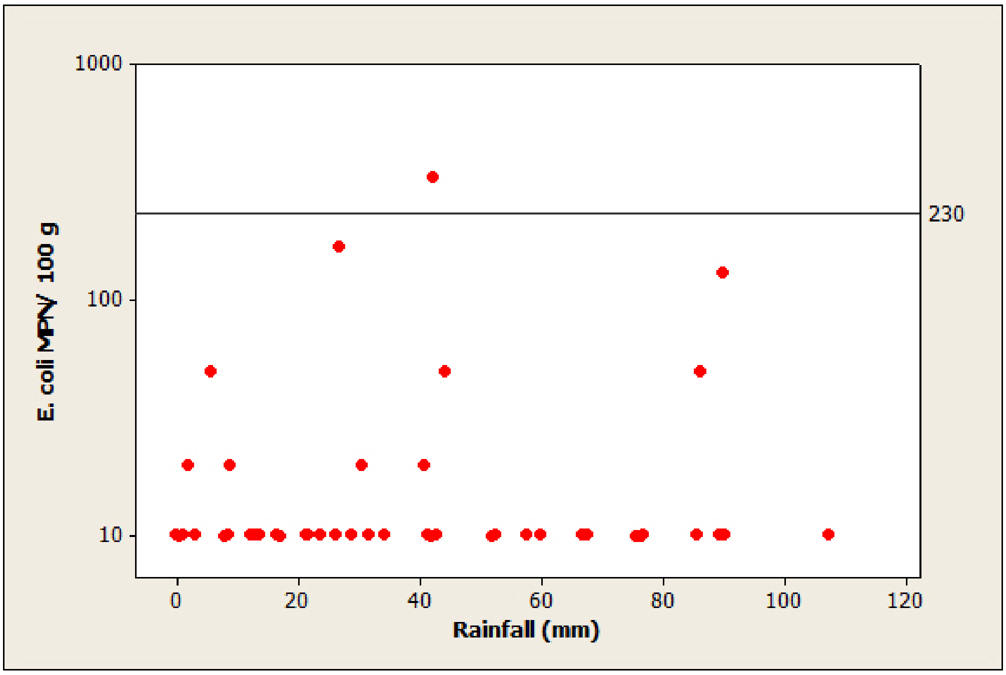


Figure 11.12 Scatterplot of Pacific oyster *E. coli* results against rainfall in the previous seven days

No significant correlation was found between Pacific oyster results and 7-day rainfall (Spearman's rank correlation r = -0.022, p = 0.885).

11.6.2 Analysis of results by tidal height and state

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 the polar plot. The tides then decrease to the smallest (neap) tides, at about 225^{o}, before increasing back to spring tides. Polar plots are presented *E. coli* results for individual species against the lunar cycle in Figures 11.13 and 11.14. It should be noted that local meteorological conditions such as wind strength and direction can influence height of tides and this is not taken into account.

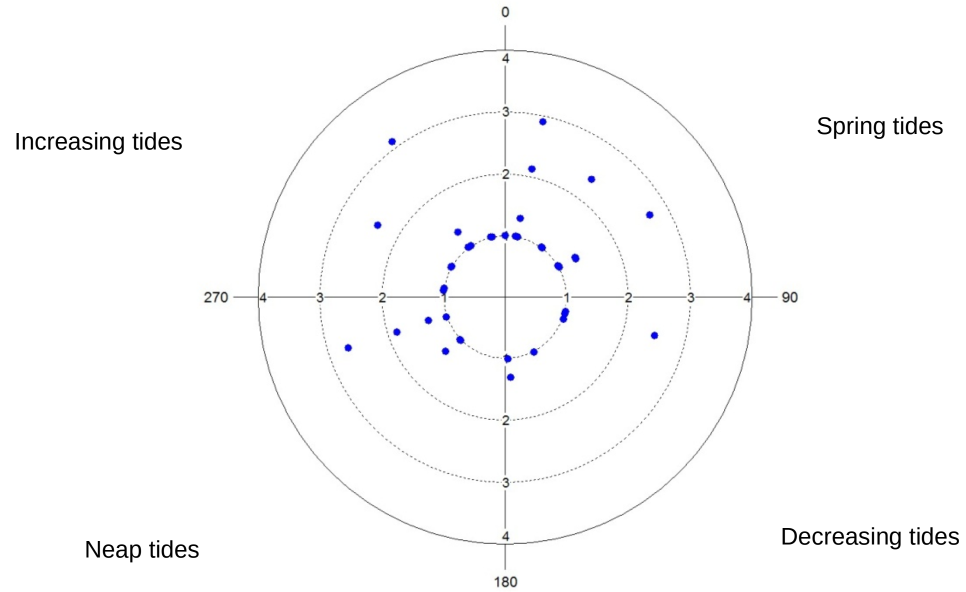


Figure 11.13 Polar plots of common mussel Log$_{10}$ *E. coli* results on the spring/neap tidal cycle

No statistically significant correlation was found between common mussel log$_{10}$ *E. coli* results and the spring/neap tidal cycle (circular-linear correlation r = 0.076, p = 0.787), although high results tended to be seen on increasing and spring tides.

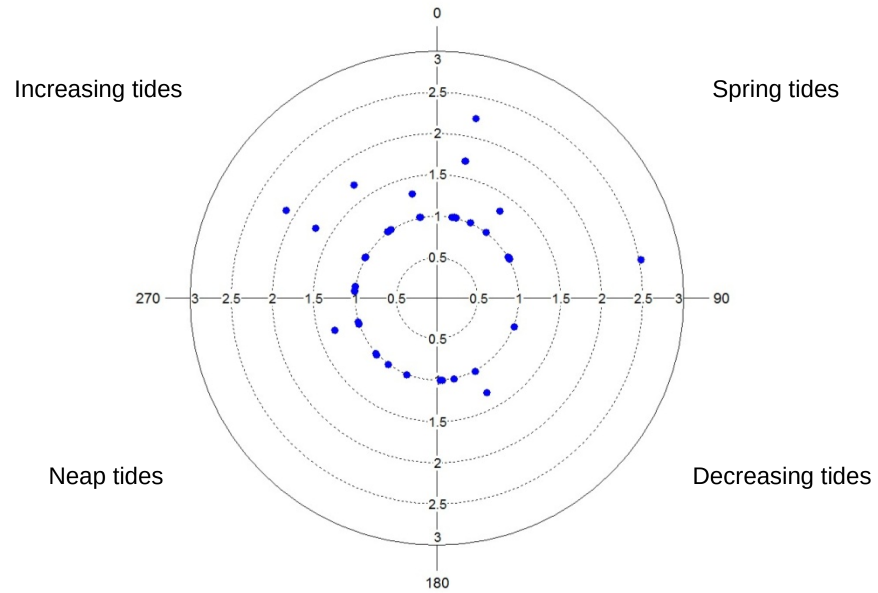


Figure 11.14 Polar plots of Pacific oyster Log$_{10}$ *E. coli* results on the spring/neap tidal cycle

No statistically significant correlation was found between Pacific oyster log$_{10}$ *E. coli* results and the spring/neap tidal cycle (circular-linear correlation r = 0.224, p = 0.098), although high results tended to be seen on increasing and spring tides. Unusually for an intertidal oyster site, samples were taken at nearly all tidal states.

Tidal state (high/low tide) changes the direction and strength of water flow around production areas. Depending on the location of contamination sources, tidal state may cause marked changes in water quality near the vicinity of the farms. Shellfish species response time to *E. coli* levels can vary from within an hour to a few hours. Polar plots in Figures 11.15 and 11.16 present *E. coli* results for individual species against lunar tidal cycle, where high water is located at 0^o and low water at 180^o.

High/Low Tidal Cycle

High and low water data from Portnancon were extracted from POLTIPS-3 in May 2013. This site was the closest to the production area and it is assumed that tidal flow will be very similar between sites.

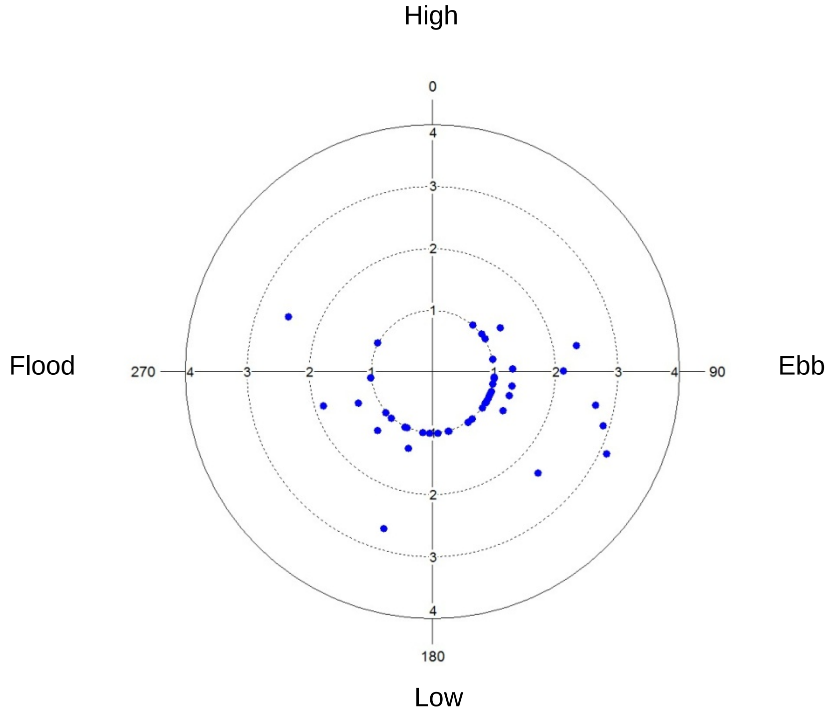


Figure 11.15 Polar plots of common mussel $\log_{10}$ *E. coli* results on the high/low tidal cycle

No statistically significant correlation was found between common mussel $\log_{10}$ *E. coli* results and the high/low tidal cycle (circular-linear correlation r = 0.088, p = 0.721), however the majority of samples were taken on an ebb/low tide, when the sampling trestles would have been uncovered.

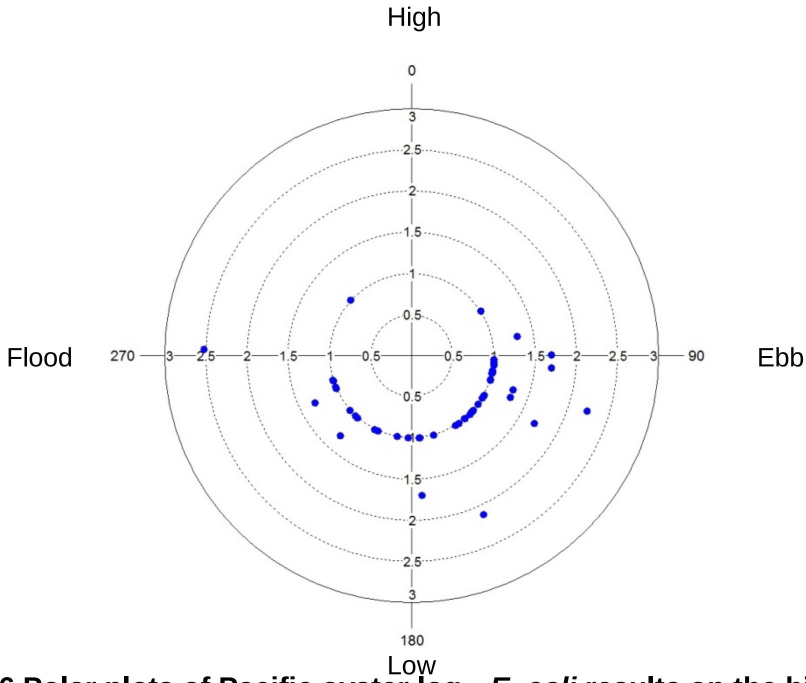


Figure 11.16 Polar plots of Pacific oyster $\log_{10}$ *E. coli* results on the high/low tidal cycle

No significant correlation was found between Pacific oyster $\log_{10}$ *E. coli* results and the high/low tidal cycle (circular-linear correlation r = 0.140, p = 0.405). Samples were usually taken on an ebb or low tide, when the trestles would have been accessible.

11.6.3 Analysis of results by water temperature

Water temperature can affect survival time of bacteria in seawater (Burkhardt, *et al*., 2000). It can also affect the feeding and elimination rates in shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. Water temperature is obviously closely related to season. Any correlation between temperatures and *E. coli* levels in shellfish flesh may therefore not be directly attributable to temperature, but to the other factors e.g. seasonal differences in livestock grazing patterns. Scatterplots present individual species *E. coli* results against water temperature in Figures 11.17 and 11.18. Twenty-seven out of the 48 common mussel results had water temperatures recorded for samples. Twenty-nine of the 52 Pacific oyster results had water temperature data assigned to them. Jittering of both common mussel and Pacific oyster individual samples results was applied at 0.02 and 0.001 on the X and Y axis respectively for both species.

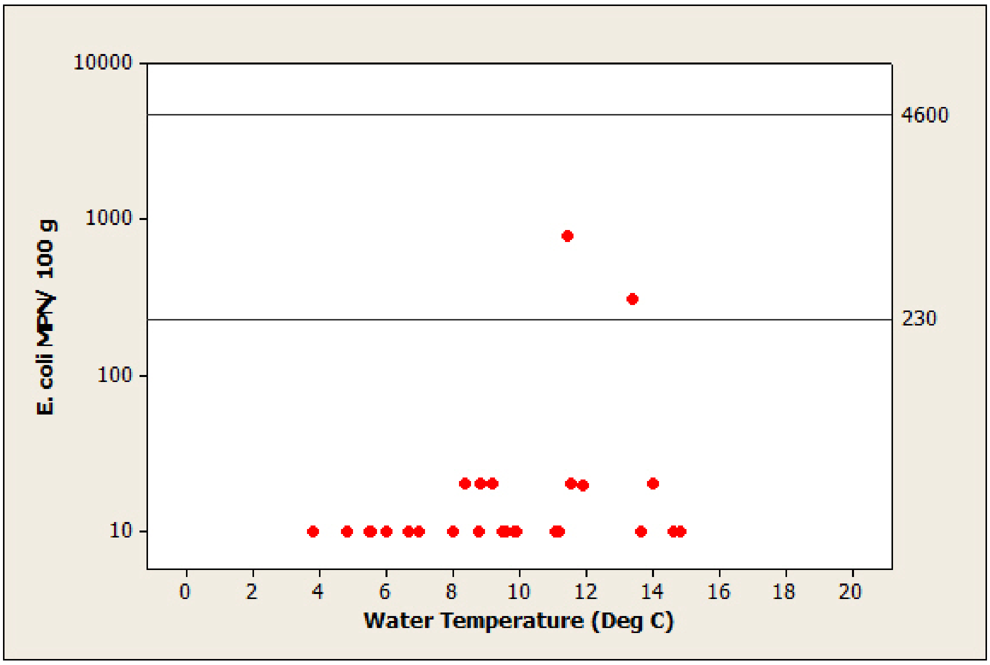


Figure 11.17 Scatterplot of common mussel *E. coli* results and water temperature

No statistically significant correlation was found between common mussel *E. coli* results and water temperature (Spearman's rank correlation r = 0.363, p = 0.068). A large number of the common mussel samples with higher *E. coli* results did not have water temperatures recorded.

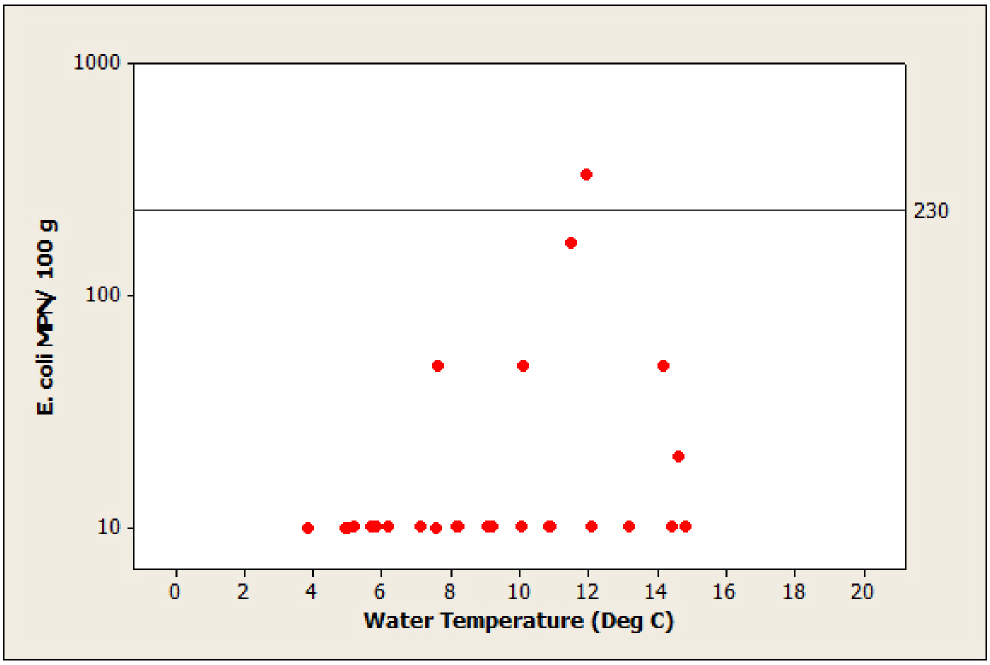


Figure 11.18 Scatterplot of Pacific oyster *E. coli* results and water temperature

No statistically significant correlation was found between Pacific oyster *E. coli* results and water temperature (Spearman's rank correlation r = 0.368, p = 0.064). Low *E. coli* results were however returned with varying water temperatures between 4 and 15.5^{o}C.

11.6.4 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence and hence freshwater-borne contamination at a site. Scatterplots present individual species *E. coli* results against water salinity in Figures 11.19 and 11.20. Salinity measurements were taken for 35/48 common mussel samples (which did not include salinity measurements from the highest *E. coli* results) and 38/52 of Pacific oyster samples. Jittering was applied to individual species results at 0.02 and 0.001 on the X and Y axis respectively.

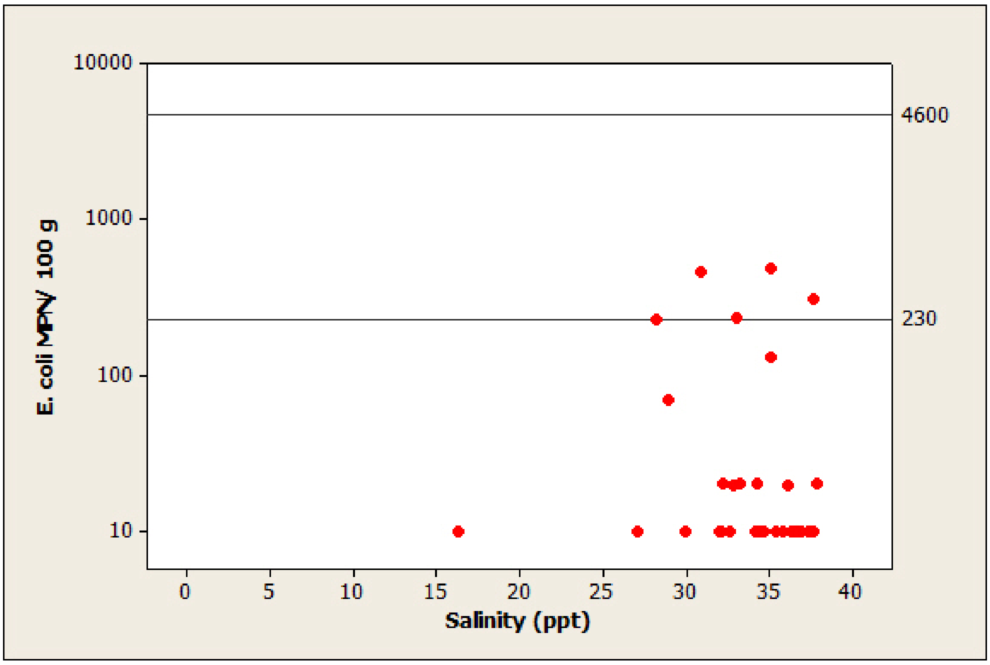


Figure 11.19 Scatterplot of Loch Eriboll common mussel *E. coli* results and salinity

No statistically significant correlation was found between common mussel *E. coli* results and water salinity (Spearman's rank correlation r = -0.135, p = 0.461).

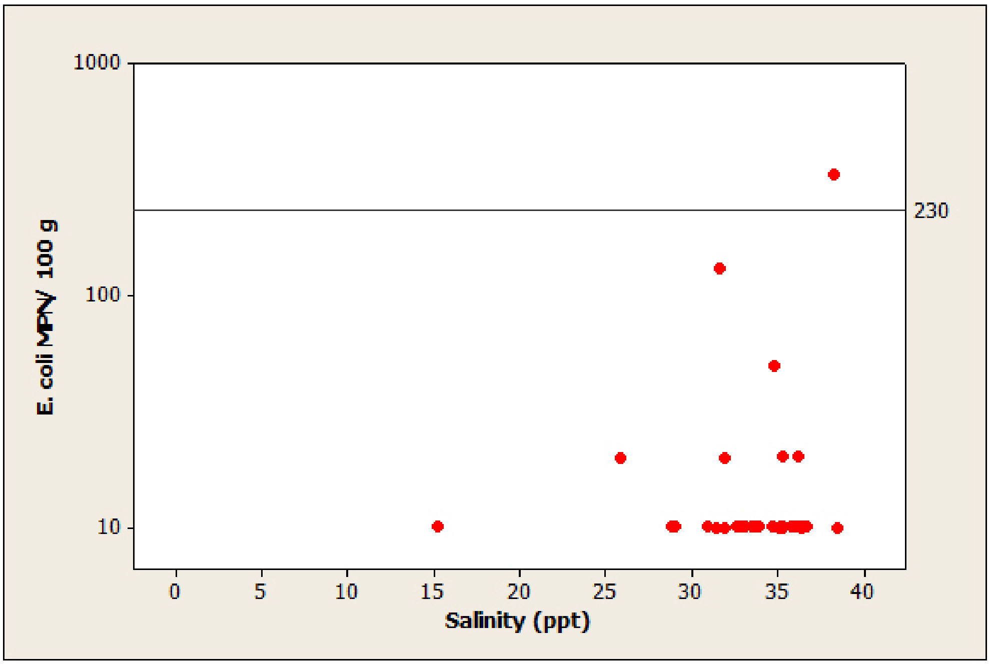


Figure 11.20 Scatterplot of Loch Eriboll Pacific oyster *E. coli* results and salinity

No statistically significant correlation was found between Pacific oyster *E. coli* results and water salinity (Spearman's rank correlation r = -0.008, p = 0.966).

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

There were too few elevated Pacific oyster samples >230 *E. coli* MPN/ 100 g to allow for comparisons. Common mussel sampling results exceeding 230 *E. coli* MPN/100 g is listed in Table 11.2.

Table 11.2 Historical *E. coli* results over 230 *E. coli* MPN/100 g

Collection Date	*E. coli* (MPN/100g)	Location	Two day rainfall (mm)	Seven day rainfall (mm)	Water Temp (^{o}C)	Salinity (ppt)	Tidal state (high/low)	Tidal State (spring/neap)
03/09/2008	310	NC 4189 5929	8.7	30.4	13.6	38	Flood	Decreasing
21/07/2010	460	NC 4189 5929	0.9	42.1	-	31	Low	Neap
21/09/2010	1300	NC 4189 5929	17.0	61.1	-	-	Ebb	Increasing
08/11/2010	490	NC 4189 5929	4.1	40.8	-	35	Ebb	Spring
18/07/2012	790	NC 4189 5928	0.0	26.6	11.5	-	Ebb	Spring

The majority of elevated results occurred in 2010. Most occurred in either July or September, with only one elevated result occurring later, in November. Sampling locations were within 10 m of one another and close to the RMP. Rainfall levels on the previous two and seven days prior to the sampling varied between 0.0-17.0 mm and 26.6-61.6 mm respectively. The highest *E. coli* result corresponded with the highest reported rainfall of all the elevated results. Water temperatures were recorded for only two out of the five results. Salinity was recorded for three out of the five results. Three of the five results were taken on an ebbing tide.

11.8 Summary and conclusions

Common mussels

Overall contamination levels within sampling results for common mussels have been low. The five results >230 *E. coli* MPN/ 100 g were taken in July, September and November. The majority of results are 20 *E. coli* MPN/ 100 g or less. Sampling locations have been similar, except for three samples that appeared to be taken at the at the mussel lines in 2008 and just below mean low water 2011. No geographical trend could be seen from results.

Statistical analysis found no significant differences between results and season. Correlations were not found between results and previous two day rainfall or seven day rainfall. No statistically significant correlation was found between results and seawater temperature or salinity. High/low or spring/neap tidal states did not have a statistically significant impact on results.

Pacific oysters

Overall contamination levels within sampling results for Pacific oysters have been very low, with only one result >230 *E. coli* MPN/ 100 g at 330 *E. coli* MPN/ 100 g. The vast majority of results were 20 *E. coli* MPN/ 100 g or less. Sampling locations were very similar, due to all samples consistently coming from trestles on the NW shoreline.

Statistical analysis found results varied with season, with summer results higher than spring results, likely to reflect uneven sampling between seasons. No correlations were found between results and rainfall on the previous two or seven days prior to sampling. No statistically significant correlation was found between results and seawater temperature or salinity. High/ low or spring/neap tidal states did not have a statistically significant impact on results.

12. Designated Waters Data

The Loch Eriboll production area and fishery lie within the Loch Eriboll, North West designated Shellfish Growing Water (SGW) (shown in Figure 12.1). The SGW was originally designated in 2000. SEPA is responsible for ensuring that monitoring us undertaken for a variety of parameters, including faecal coliforms in shore mussels.

The monitoring point used by SEPA is NC 44911 58396 (SEPA, 2011). Since 2007, SEPA have obtained shellfish classification monitoring results (*E. coli*) under an agreement with FSAS for the purposes of SGW monitoring. Those results have been used in the analysis in Section 11 of this report and so are not repeated here. The SGW has consistently complied with the Guideline standard for faecal coliforms since monitoring began in 2000.

The relative positions of the production area, RMP, Shellfish Growing Waters (SGW) boundary and the SGW monitoring point are shown in Figure 12.1.

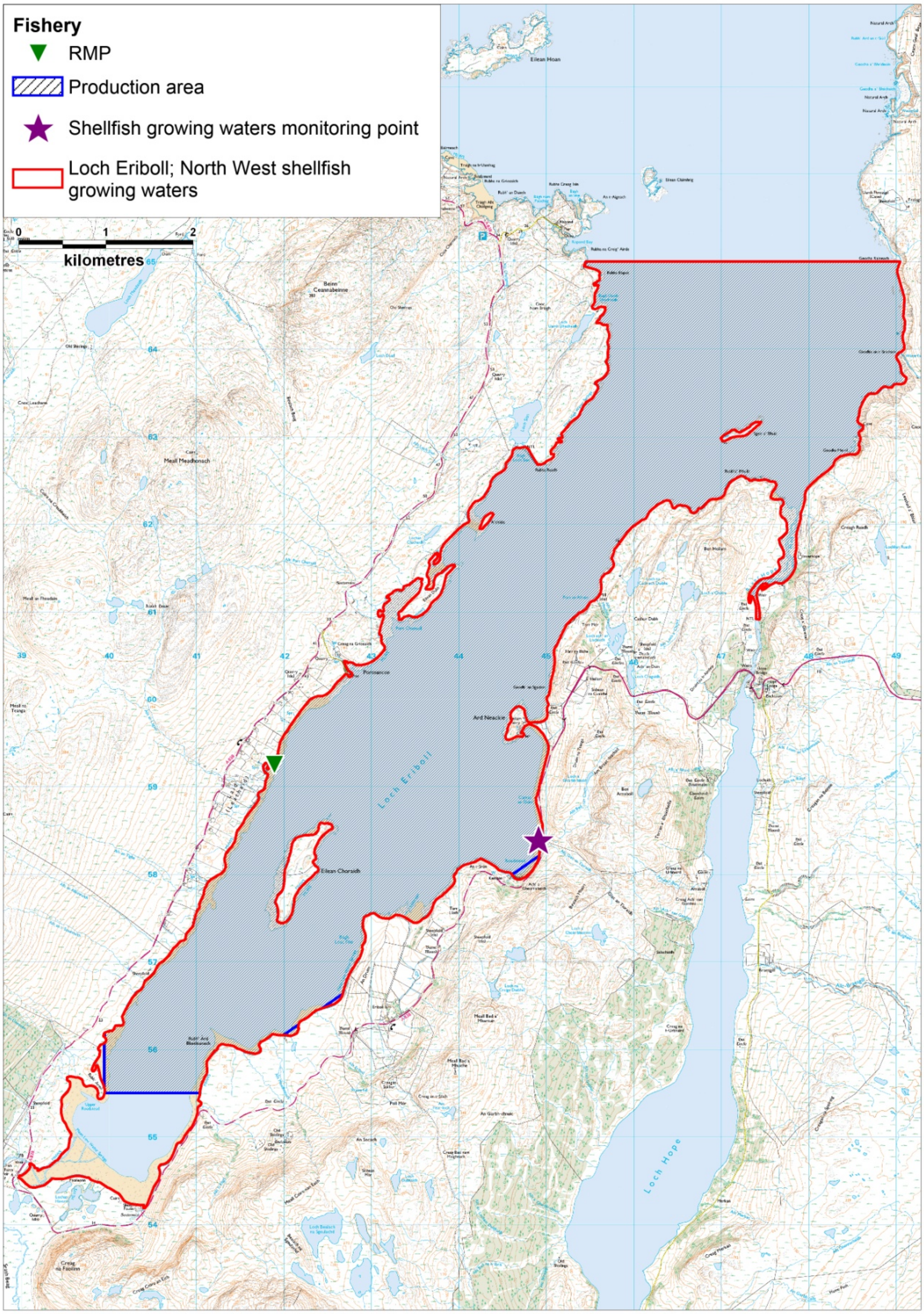


Figure 12.1 Designated shellfish growing water – Loch Eriboll, North West

13. Bathymetry and Hydrodynamics

13.1 Introduction

The Study Area

Loch Eriboll is a deep sea loch situated on the NW tip of Scotland and lies to the east of Cape Wrath. It is unique from other Scottish large deep sea lochs in that it is the only loch exposed to the north. The Kyle of Durness and the Kyle of Tongue which both flank Loch Eriboll have a sand and mud composition and are not true sea lochs. It has a north-east facing aspect and the area contains five crofting townships which are all small in size. Heilam is the first settlement at the mouth of the loch in the northeast and opposite is Portnancon on the NW. Laid is south of this on the mid-west and is the largest settlement around the loch. On the mid-east is Eriboll and Polla lies on the south at the head of the loch. At the north of the loch lies Eilean Hoan with another larger island situated in the south of the loch, Eilean Choraidh. There are a number of small islets throughout the area. The study area is shown in Figure 13.1

Coordinates for the middle of Loch Eriboll:

58° 29.52’ N 004° 41.37’ W
NC 43337 59125

Figure 13.1 Extent of hydrographic study area

13.2 Bathymetry and Hydrodynamics

13.2.1 Bathymetry

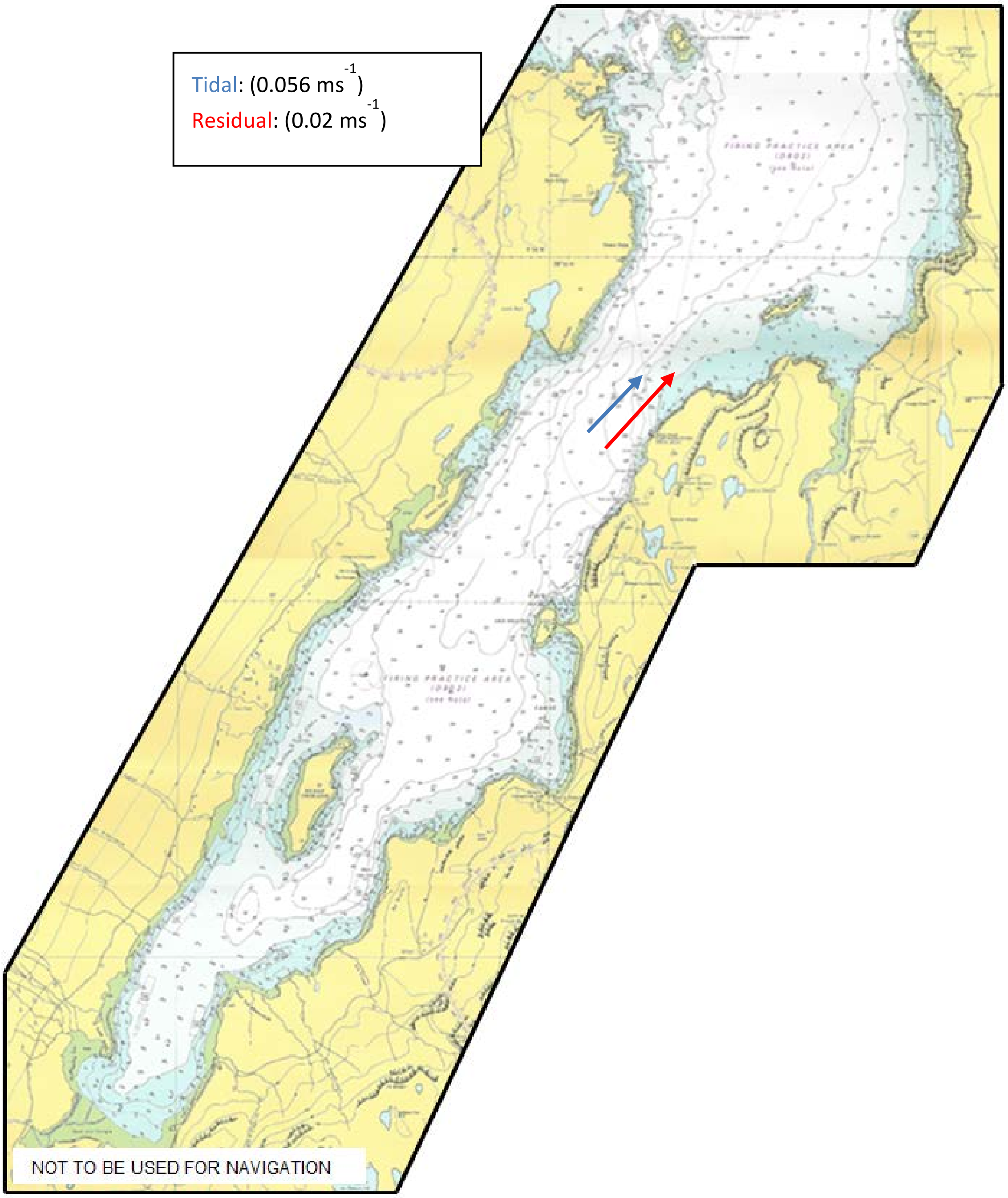


Figure 13.2 Admiralty chart (2076) extract for Loch Eriboll. Net cumulative displacement through tidal flow (ebb) and residual flow are shown. See section 13.3.1 for further commentary

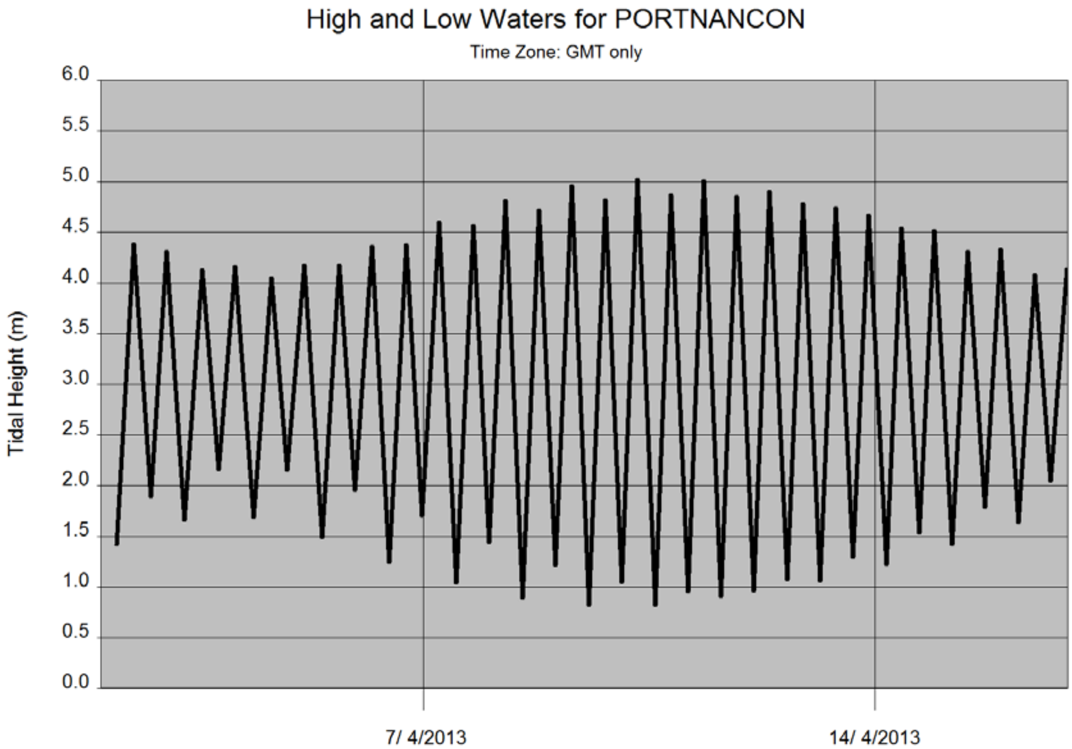
Figure 13.2 shows the bathymetry of Loch Eriboll, the largest and only true sea loch on Scotland's extreme north coast and one of the most sparsely populated areas in the UK. In general, the loch has relatively simple topography. The loch is 15.5 km in length and

2 km in width with a maximum depth of 68 m (Edwards & Sharples, 1986). There is a sill of 38 m depth near the entrance of the loch which probably does not inhibit the good flushing in the upper and middle reaches (Highland Council Planning and Development Service, 2000) or exchange with the open ocean to the north. At high water, it has a surface area of 32.4 km^2 with the intertidal area making up approximately 4% of this (Highland Council Planning and Development Service, 2000; Edwards & Sharples, 1986). At low water, the surface area is 31.1 km^2 with an estimated mean low water depth of 25.8 m and a low water volume of approximately 8.0 x 10^8 m^3 (Edwards & Sharples, 1986). Its main basin is situated between Rubha Ruadh to the north of the loch and the peninsula in the middle of the loch, Ard Neackie. The loch perimeter is generally steep–sided where depths quickly reach > 12 m within approximately 150 - 200 m from the shore. The exception is the head of the loch which gently slopes to > 10 m. The current shellfishery is located to the north west of Eilean Choraidh.

13.2.2 Tides

Loch Eriboll has a small range of tidal motion and has a typical semi-diurnal tidal characteristic. Data on tidal information is given from charted information. The nearest location for tidal predictions is Portnancon situated in the middle of Loch Eriboll [http://easytide.ukho.gov.uk].

Standard tidal data for Loch Eriboll are given below and the spring/neap cycle of tidal height around the time of the survey (8 - 10 April 2013) is shown in figure 13.3:



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

Figure 13.3 Two week tidal curve for Portnancon, Loch Eriboll

Tidal Heights for Portnancon, Loch Eriboll (from Admiralty Chart 2076):

Mean High Water springs = 5.1 m
Mean Low Water springs = 1.1 m
Mean High Water neaps = 4.1 m
Mean Low Water neaps = 2.2 m

Tidal Ranges:

Mean spring Range = 4.0 m
Mean neap Range = 1.9 m

This gives a tidal volume of water during each tidal cycle of approximately:

springs: 1.2×10^8 m^3
neaps: 0.6×10^8 m^3

13.2.3 Tidal Streams and currents

There are no tidal diamonds for this area. Enhancement of tidal streams caused by straights and channels are negligible in Loch Eriboll due to its relatively simple bathymetric topography. However, there may be some localised effects around Eilean Choraidh, the large island towards the lower half of the loch, the peninsula of Ard Neackie in the middle and perhaps around several smaller islands to the north, Sgeir a' Bhuic and Eilean Cluimhrig.

There are a number of sources of current meter data available from previous surveys. Current meter data and reports were obtained from SEPA for surveys two at two sites in Loch Eriboll, Sian Bay (Aurora Environmental Ltd, 2003) and Kempie (Xodus Group, 2011). They typically span 15 days; being the half-lunar period required to capture a spring-neap cycle. In these reports, near-bed refers approximately to 2 m above the seabed, mid-depth is typically 8 m above the seabed and sub-surface is 10-12 m above the seabed.

Data from Sian Bay, Loch Eriboll were collected in 2002 (Aurora Environmental Ltd, 2003) summarised in Table 13.1. Semi-diurnal periodicity along with some spring-neap variation was displayed throughout the velocity readings. In general, the currents were of a moderate velocity and whilst the tabulated mean velocity is greatest in the sub-surface, overall there was similarity between current velocities at all depths. The data has rather little technical narrative accompanying it. This survey reports that the surface and mid-water current vectors in Sian Bay were generally flowing north-south and the current vectors near the bed were flowing in a north-east to south-west direction; in general following the bathymetric contours. Overall, compared to other sea lochs, this survey suggests that the Sian Bay site in Loch Eriboll is moderate to weakly-flushed.

Table 13.1 Sian Bay, Loch Eriboll current data measured in 2002

	Near-bed	Mid	Sub-surface
Mean Speed (ms^{-1})	0.037	0.042	0.046
Principal Axis Amp (ms^{-1}) & Dir	0.043 (NE-SW)	0.054 (N-S)	0.056 (N-S)
Residual speed (ms^{-1})	0.013	0.016	0.019
Eccentricity Ratio	1.1	1.5	1.4
Residual direction (^oM)	32	359	352

Based upon a measured surface principal current amplitude of 0.056 m/s (Table 13.1) and the assumption of a uniform sinusoidal tide, the cumulative transport that might be expected in the surface during each phase of the tide has been estimated as approximately 0.75 km. No distinction is made here for springs and neaps, nor has any estimate been made for any seasonal variation.

Data from Kempie, Loch Eriboll were collected in 2011 (Xodus Group, 2011) summarised in Table 13.2. Semi-diurnal periodicity along with some spring-neap variation was displayed throughout the velocity readings. In general, the currents were of a moderate-low velocity. The tabulated mean velocity is greatest near the seabed, however the differences are so marginal that it can be concluded that there was a similarity between current velocities at all depths. It should also be noted that the technical narrative accompanying this report comments that the value of the near-bed current velocity is an anomaly and shows a higher than normal value for this depth. They conclude that this was due to a mechanical error with the ADCP.

This survey reports that the surface and mid-water current vectors in Kempie were generally flowing south-west and the current vectors near the bed were flowing in a south-east direction. Given that the deployment was in a small bay to the north of Kempie, it is difficult to conclusively state what is determining the current direction. However, near the bed the flow appears to be broadly following the topography. However, given the low eccentricity ratio it is clear that there is no strong steering of the surface or midwater currents. Overall, this survey suggested that the Kempie site in Loch Eriboll is weakly flushed.

Table 13.2 Kempie, Loch Eriboll current data measured in 2011

	Near-bed	Mid	Sub-surface
Mean Speed (ms^{-1})	0.029	0.028	0.027
Principal Axis Amp & Dir (ms^{-1}) & (^oM)	0.037 (150)	0.036 (215)	0.033 (215)
Eccentricity Ratio	1.44	1.23	1.18
Residual speed (ms^{-1})	0.011	0.006	0.006
Residual direction (^oM)	102	209	201

Based upon a measured surface principal current amplitude of 0.033 m/s (Table 13.2) and the assumption of a uniform sinusoidal tide, the cumulative transport that might be expected in the surface during each phase of the tide has been estimated as approximately 0.4 km. No distinction is made here for springs and neaps, nor has any estimate been made for any seasonal variation.

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 Eriboll. Without such data it is difficult to judge what the dispersive environment might be like, but the occurrence of small promontories on the east side of the bay, occurrence of islets and the reported tidal flow along this coast may enhance dispersion in that location.

Dispersion of surface contaminants may be enhanced by wave energy within Loch Eriboll. Sources of wave energy are from both short period waves that are created within the loch itself and from swell conditions that have a much larger period originating in the North Atlantic (Ramsay & Brampton, 2000). Longest fetch lengths occur in the north east/south west direction and the biggest wind generated waves are produced from these wind directions. The area most affected by winds originating from the northern quarter is the wide outer part of the loch and resulting in powerful wave action in shallow water. Within the middle of the loch, there is usually only a small fetch. However it is possible that large swells can be present in this area (Moss, 1989).

13.2.4 River/Freshwater Inflow

The source of river inflow into Loch Eriboll is primarily from two watercourses; Amhainn an t-Sratha Bhig which flows past Polla situated to the south and Allt an Lagain which flows through Laid to the west of the loch. The River Hope is also a substantial contributor of fresh water input into Loch Eriboll and it lies, somewhat unusually, adjacent to the mouth of the loch. Other rivers flowing into the loch are Allt an t-Sasunnaich, Allt an Albannaich, Allt an Tighe, Allt Meadhonach and Allt Eriboll all lying to the south of the loch. There are other unnamed rivers on the OS chart which may or may not flow depending on the season.

The annual precipitation in the area is approximately 1500 mm and the annual freshwater run-off is estimated as 134.0 Mm^3yr^{-1} (Edwards & Sharples, 1986). The ratio of freshwater flow to tidal flow in Loch Eriboll is low at approximately 1:500 and therefore the input of freshwater has very limited influence over the salinity of the loch as a whole.

13.2.5 Meteorology

The most dominant wind quadrant is that of south and west, particularly in the winter. However, winds from the south east can be prevalent but primarily in the spring and summer months.

The narrow profile and the north east aspect result in Loch Eriboll being reasonably sheltered from prevailing winds from the west. However, north and north-westerly winds affect the outer area of loch and south-westerly winds to a lesser extent as compared to the relatively sheltered inner loch (Highland Council Planning and Development Service, 2000). The south of the loch is very sheltered from winds.

The hourly mean windspeed in Loch Eriboll, exceeded for 75% of the time, is approximately 4 m/s and the hourly mean windspeed, exceeded for 0.1% of the time is 20 m/s(Caton, 1976).

13.2.6 Model Assessment

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

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, exchange between the layers and the flushing time, which is the inverse of the exchange rate. These values are given in Table 13.3

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

Parameter	Value
Tidal Volume Flux ($m^3\ s^{-1}$)	399
Estuarine Circulation Volume Flux ($m^3\ s^{-1}$)	70
Wind Driven Entrainment between upper and lower layer ($m^3\ s^{-1}$)	23
Tidal and Density driven entrainment between upper and lower layers ($m^3\ s^{-1}$)	23
Median Flushing Time (days)	18
95%-ile Flushing Time (days)	29

The ratio of Tidal volume flux to estuarine circulation volume flux is 5.7. Values greater than 2 indicate a system that is strongly tidal in its exchange characteristics (Gillibrand, et al., 2012).

The flushing time for Loch Eriboll is estimated at around 18 days which is bigger than the value for the simplified tidal prism model suggesting that the exchange environment is more complex.

13.3 Hydrographic Assessment

13.3.1 Surface flow

The site and the meteorological data indicate that there is likely to be a rather minimal freshwater discharge into the surface waters of the loch, though the absolute value of discharge would have moderate seasonal variation.

The Loch is relatively long so there is likely to be significant variation in properties of the surface properties along the axis of the loch. The relatively small freshwater discharge would suggest that stratification might dominate only under exceptionally calm conditions, but given the generally expansive nature of the loch the water column would most likely be well mixed in most cases.

Surface flows would be enhanced/retarded by winds blowing out of/into the loch, particularly from the dominating southerly or southwesterly directions, and also further enhance the mixing of the waters through the full depth.

Underlying the estuarine flow is the tidal flow running approximately southwest on the flood and northeast on the ebb. The principal current direction of the surface water has, from rather short surveys of the local currents, been shown to flow in alignment with the shoreline. Cumulative transport during each phase of the tide is estimated to be around 0.75 km.

Net transport of contaminants is related to the residual flow presented in Figure 13.2 and documented in Table 13.1. The residual surface flow measured in the surface waters of Sian Bay (Aurora Environmental Ltd, 2003) follow a generally northerly direction. This can be interpreted as a weak outflow of the surface waters. With the measured surface residuals of order 0.02 m/s, the net transport over a tidal cycle of approximately 12 hours would be less than 1 km. It is likely that residual flow alone would not flush surface contaminants effectively. Note in Figure 13.2 that the residual flow acting over approximately 12 hours is longer than the tidal flow over a single phase of the tide (in this case the ebb). This is because the peak flow will only act for 1-2 hours of the 6.2 hour ebb period.

Given the current meter measurements in Sian Bay it is likely that any surface contaminant would be transported primarily along the axis of the loch. The dispersive characteristics of the site are unknown but there will be enhanced dispersion as the flow encounters promontories and islands along the path of the flow and in periods of strong wind.

13.3.2 Exchange Properties

The key aspect of the model output in terms of the exchange is that the tidal volume flux dominates the estuarine (or gravitational) volume flux by a factor of 5.7. This means that exchange of waters in Loch Eriboll is principally a tidally driven process. Hence there is likely to be rather little seasonal variation in the flushing time of the Loch. The model predicts that 95% of the time the flushing time will be 29 days or less.

One might describe the flushing characteristics of Loch Eriboll as being ‘weakly flushed’, however the prevailing winds from the south and west may enhance surface flushing rates. Subsurface exchange will probably have similar exchange characteristics as the surface water, however, the enhanced exchange and dispersion that might occur in the surface due to wind affects would be rather limited in the deeper waters.

There is a limited amount of available current meter data for Loch Eriboll and there is a paucity of any measured hydrographic data. However, there is a simple model assessment of exchange available. Therefore the confidence level of this assessment is MEDIUM.

14. Shoreline Survey Overview

The shoreline survey at Loch Eriboll was conducted between the 8th and 10th April 2013. No precipitation fell in the 48 hrs prior to the survey and it was noted that in the two months preceding the survey period, little rainfall had fallen over the survey area. Short hail showers fell on the second and third days of sampling.

The fishery in Loch Eriboll consisted of common mussel cultivation on long lines, with 2 active sites and two areas with derelict lines. Twelve trestles were present on the intertidal shore on the west side of the loch, with sufficient Pacific oysters and samples on site for sampling purposes only.

Houses were noted along much of the shoreline. On the eastern shore of the loch there were no direct discharges onto the shore, and the only habitation noted consisted of a small cluster of houses around the farm at Eriboll. There was one house at the south of the loch, with the majority of homes along the crofting township of Laid. A group of homes was seen at Portnancon, where there was a septic tank that appeared to serve the group, though no outfall pipe was identified.

No campsites, caravan parks or hotels were seen within the survey area. One B&B was seen in Laid, and several self-catering properties were found between Laid and Portnancon. Subsequent to consultation on the draft of this report, the sampling officer identified that there is a campsite accommodating tents and touring caravans adjacent to the cafe at Laid.

Several boats were observed during the survey including a workboat which was used to serve the fish farm from the shore base at Port Chamuill, small creeling fishing boats, and some recreational boats. Two piers were observed; one at Ard Neackie and another at Portnancon. Both were small and only usable at high tide. Personal boats were also observed hauled out on shore at several locations.

Livestock seen were mainly sheep, although on the western side of the loch smaller crofts had a greater diversity of animals, with goats and ducks also present on the farmland. Some cattle were seen at a farm along the main road in the village of Laid, but were not observed as part of the survey route.

On the eastern shore of the loch the land was used for farming, the improved grassland around Eriboll farm giving way to rough grazing over the rest of the shoreline area. North of Laid, there were further crofts and rough grazing.

A small area of native woodland was found near Kempie and a larger area of plantation woodland to the southwest corner of the bay.

The largest watercourse encountered on the survey route was a river discharging through Strath Beag into the southwest corner of the loch. All of the other watercourses encountered were much smaller than this. Several dry streams were noted.

Little in the way of wildlife was observed during the survey.

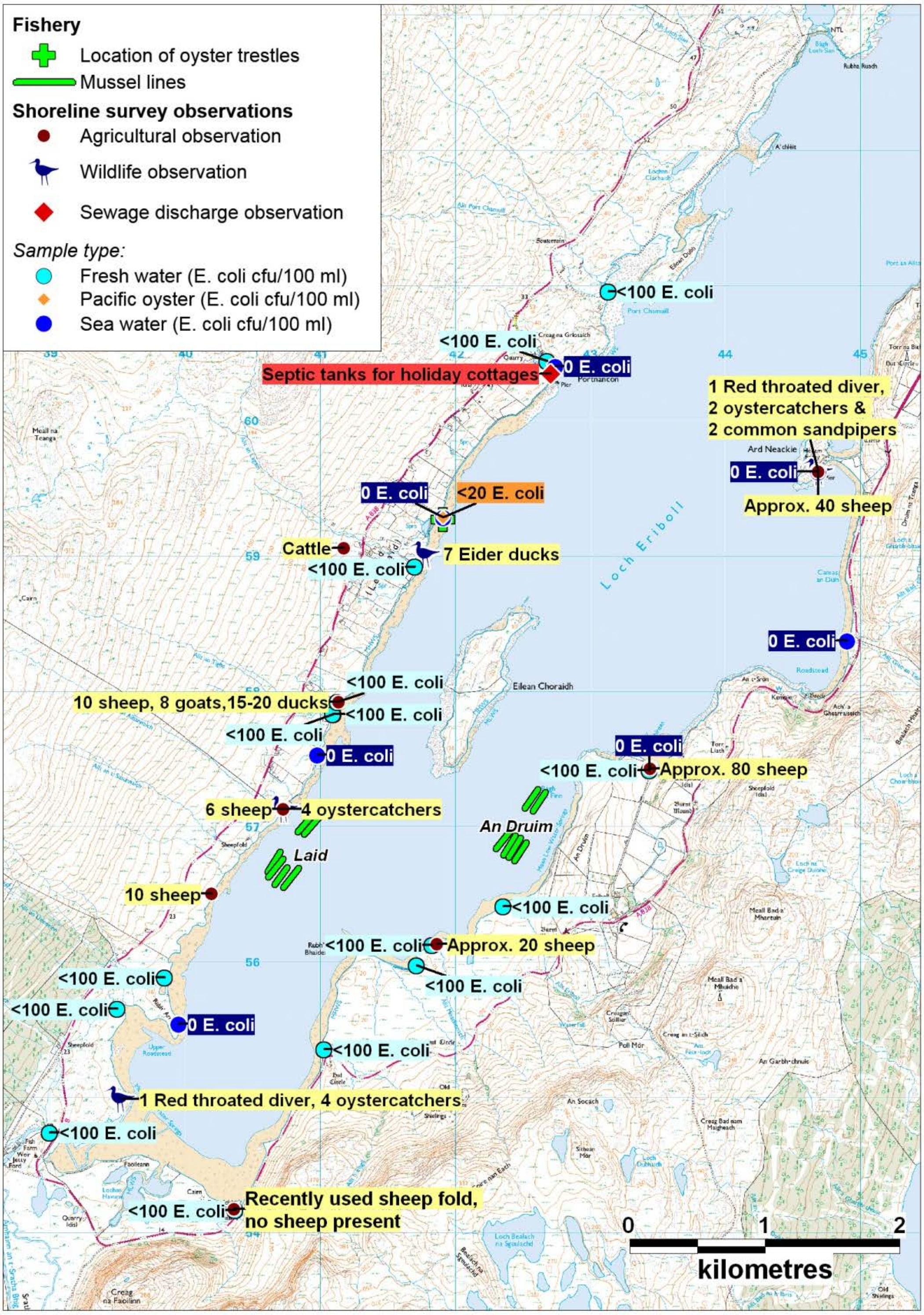


Figure 14.1 Map of shoreline survey observations at Loch Eriboll

15. Overall Assessment

Human sewage impacts

Overall, the risk of contamination to the mussel fisheries in Loch Eriboll is relatively low due to the very small population in the area. There is no public sewerage provision, and the majority of homes at Laid have septic tanks discharging to soakaway systems set well inland of the shoreline. One septic tank and a trade discharge from a water treatment works discharge to the Allt an Lagan, which flows into the loch approximately 400 m southwest of the RMP trestles. Discharges from cottages at Portnancon and Port Chamuill, 1.3-1.9 km northeast of the RMP, are either to sea or to soakaway systems at or below MHWS. However, due to the distance from the active mussel fisheries in the south of the loch these are considered unlikely to significantly impact water quality at the mussel farms.

Agricultural impacts

Agricultural activity around the loch is limited to crofting and livestock rearing. A significant number of sheep are kept within the agricultural parish and a moderate number of animals were seen during the shoreline survey. Sheep predominate, with flocks grazing most of the hillsides around the loch. It is expected that the sheep and any cattle will be kept nearer the crofts during winter and early spring, and therefore impacts from livestock would be higher along the shore at Laid where watercourses drain crofted land and where animals have access to the shoreline. Any contamination arising from Laid would impact most at the trestle area due to its close proximity to shore. A lesser impact would be likely at the northern end of the Laid mussel lines, which are set at the southern extent of the crofts.

There is a farm at Eriboll, on the east side of the loch head, and this is also expected to be a focus of any agricultural source faecal contamination. However, this area is separated from the adjacent shore by a ridge and any rainfall runoff from the farm area would tend to be carried northward to reach the loch approximately 1 km north and east of the northern end of the An Druim mussel lines.

Wildlife impacts

Seabirds and seals are present in the loch, with seabirds most numerous near the mouth of the loch and on Eilean Choraidh where there is a breeding colony of gulls. Large numbers of eider ducks may also be present at or near the mussel farms. These and the gulls are likely to be the most significant wildlife source of faecal contamination to the mussel farms and their impact would be seasonally higher in summer, when a greater concentration of birds is nesting in the area. Impacts from the colony would be higher along the eastern side of the loch, where the island is closer to the mussel farm at An Druim. However, impacts from eider ducks feeding at the mussel farms and from gulls resting on the floats would be more direct and risk of this is presumed to be even across the farms.

Seals breed in sea caves around the mouth of the loch and while it is presumed they will use much of the loch for hunting, there is no evidence to suggest that they will be present around the farms on a regular basis.

Seasonal variation

Some seasonal variation in human and animal populations is expected, with numbers of all expected to be higher in summer. There is seasonal accommodation in the area, with B&Bs and self catering accommodation present around the loch. Some evidence of seasonal variation in monitoring results is seen, with higher results occurring from July to October.

Rainfall varied by season, with the early summer months being driest and rainfall increasing from September onward.

Rivers and streams

Any contamination likely to reach watercourses discharging to Loch Eriboll will be from diffuse sources, predominantly livestock and wildlife. All water samples taken during the shoreline survey returned results below the limit of detection of the test applied, and therefore no meaningful comparison of loadings between watercourses was possible.

It is likely that flow and faecal contamination levels would be higher in the watercourses after significant rainfall. Although it is not possible to predict what the effects might be, in general the impact from any faecal contamination carried in watercourses would be higher from larger watercourses and from those that discharge very near to shellfish farms. Therefore, highest impacts at Loch Eriboll would be expected at the trestle area, which lies close to a watercourse that is likely to receive both livestock and human source faecal contamination.

Any contaminants carried via the Amhainn an t-Sratha Bhig, at the head of the loch, would be most likely to impact the southern end of the Laid mussel farm, while smaller watercourses along the adjacent shore to the west of the mussel line discharge near the southern and northernmost extents of the lines.

No statistically significant correlation was found between *E. coli* results in both species with either 2-day or 7-day antecedent rainfall.

Movement of contaminants

Very little information was available on movement of waters within the loch. Tidal flows are predicted to predominate, with a flushing time of 18 days suggesting that these flows are relatively low. Predicted tidal excursions of 1km or less, in a directly roughly parallel to shore, suggest that contaminants are unlikely to be carried very far from source, and therefore sources very close to the fisheries are likely to be more important in terms of shellfish contamination than those even a relatively short distance away. The loch is large and deep, and therefore there is substantial potential for dilution.

Temporal and geographical patterns of sampling results

Due to the collection of the majority of samples from the trestles, it was not possible to assess spatial variation of *E. coli* at the current mussel farm locations. Within the area sampled, there was no apparent geographic trend in results for common mussels. Higher results in Pacific oysters tended to occur higher up the shoreline and at the RMP. However, the majority of results for both species were at or below the limit of detection (20 *E. coli* cfu/100 g).

The overall trend over time for both species was for generally consistently low results. There was, however a peak 2010 mussel results, when approximately 40% of results (n=3) exceeded 230 MPN/100 g. The reason for this peak is unclear. Though no concurrent peak was seen in the Pacific oyster results, the highest recorded result in this species also occurred during 2010, suggesting that a contamination levels were higher at the trestles area during that time.

Conclusions

The size of the loch, lack of large scale farming and the small human population all suggest that contamination levels in water around the fishery are likely to be very low overall. This is confirmed by the historical monitoring results, which despite having come largely from an intertidal area near the largest concentration of crofts on the loch have been largely below the limit of detection of the MPN test.

The Pacific oyster fishery at Loch Eriboll is no longer active, with the trestles currently stocked for sampling purposes only. The mussel fishery is located in the southern end of the production area, with two farms currently maintained in a reasonable state. Lines on two remaining leases appeared to have been left derelict. It was not possible to ascertain where the sites identified in the classification document were located. The site names used by the harvester differ from those in use by FSAS and therefore the harvester's names have been used in this report. There appeared to have been some stock on the farms at the time of shoreline survey, based on the buoyancy and numbers of mussel floats on some of the lines as ascertained from photographs taken on the day. This suggests that the farm could potentially be harvested in the near to mid term.

16. Recommendations

Based on the state of the Pacific oyster fishery, it is recommended that this area be declassified for Pacific oysters until such time as commercial production is resumed in the loch. Should this fishery be resumed, the recommendations should be reviewed.

Recommendations below therefore pertain to the common mussel fishery currently located in the southern end of the loch.

Production area

Given the locations of the seabed leases, and the exposed aspect of the outer loch, it is not necessary to retain the northern end of the loch within the classified boundary. Therefore it is recommended that the production area be curtailed at its northern boundary to better reflect the area used for shellfish aquaculture. The recommended boundaries are the area bounded by lines drawn from NC 4232 6000 to NC 4400 6000 to NC 4400 5808 and from NC 4000 5621 to NC 4000 5550 to NC 4106 5550 and extending to MHWS.

RMP

As the trestle area lies nearest to potential contamination sources and is proven to be accessible for monthly monitoring, it is recommended that the RMP be retained at this location. It is recommended that the RMP be moved to the southern end of the trestle area at NC 4188 5923 in order to better reflect contamination arising from watercourses to the south.

Tolerance

The recommended sampling tolerance is 10 metres as the sample location is a trestle.

Frequency

Sampling frequency should be monthly, as a clear seasonal trend was seen in historical monitoring results.

Depth

Sampling depth is not applicable.

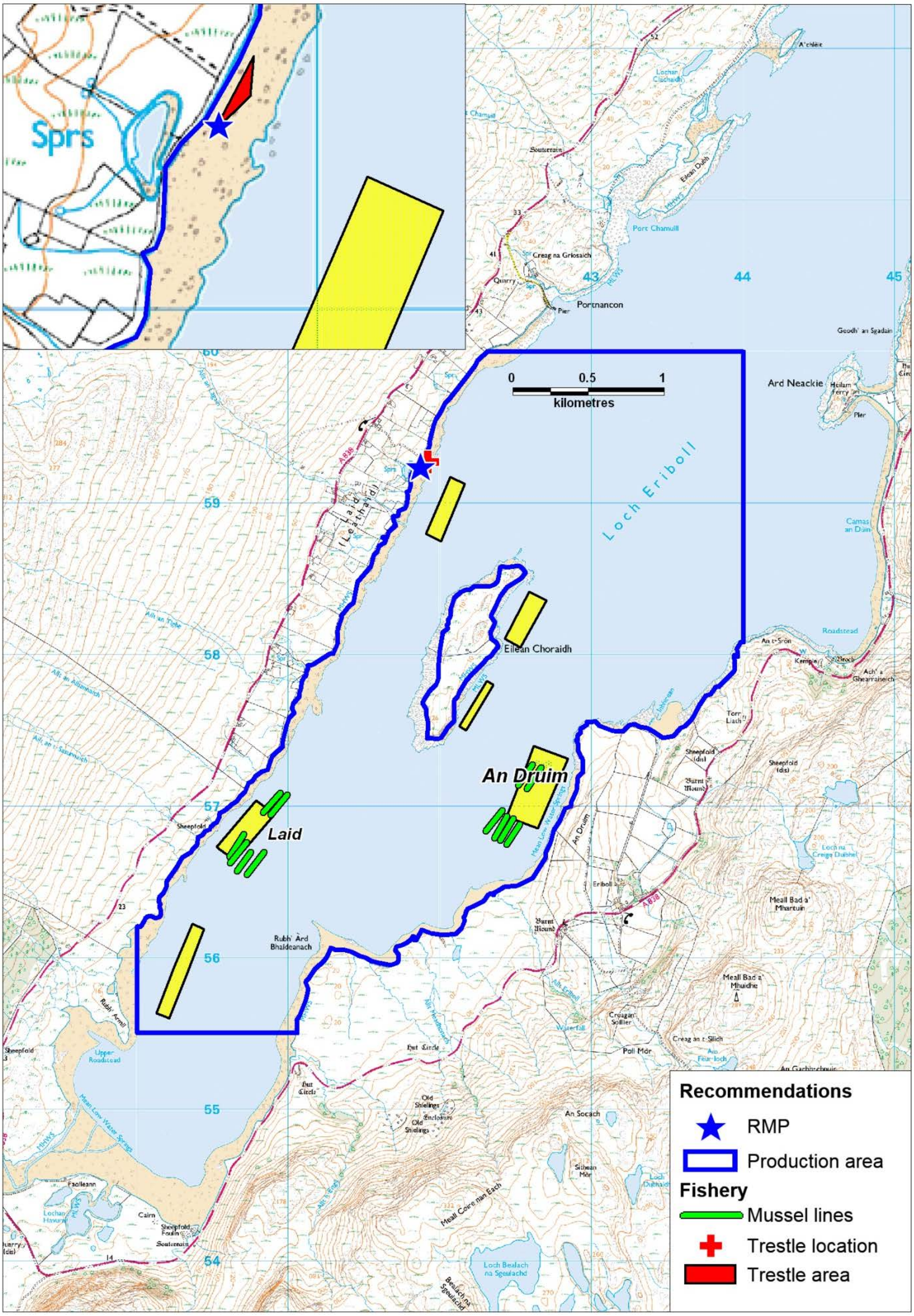


Figure 16.1 Map of recommendations at Loch Eriboll

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18. List of Figures and Tables

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1. **General Information on Wildlife Impacts**
2. **Tables of Typical Faecal Bacteria Concentrations**
3. **Statistical Data**
4. **Hydrographic Section Glossary**
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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 1.21×10^4 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 x 10^5 faecal coliforms (FC) per faecal deposit and ring-billed gulls (*Larus delawarensis*) approximately 1.77 x 10^8 FC per faecal deposit to a local reservoir (Alderisio & DeLuca, 1999). An earlier study found that geese averaged from 5.23 to 18.79 defecations per hour while feeding, though it did not specify how many hours per day they typically (Gauthier & Bedard, 1986)

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

Deer

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

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

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

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

Other

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

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

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2. Tables of Typical Faecal Bacteria Concentrations

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

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	$1.7 \times 10^{7*}$ (+)	1.4×10^7	2.0×10^7	282	$2.8 \times 10^{6*}$ (-)	2.3×10^6	3.2×10^6
Crude sewage discharges	252	$1.7 \times 10^{7*}$ (+)	1.4×10^7	2.0×10^7	79	$3.5 \times 10^{6*}$ (-)	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	$1.0 \times 10^{7*}$ (+)	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	$3.3 \times 10^{5*}$ (-)	2.9×10^5	3.7×10^5	184	$5.0 \times 10^{5*}$ (+)	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	$2.8 \times 10^{5*}$ (-)	2.2×10^5	3.5×10^5	93	$5.1 \times 10^{5*}$ (+)	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		

results of t-tests comparing base- and high-flow GMs for each group and type.

Source: (Kay, et al., 2008)

Table 3 – Geometric mean (GM) and 95% confidence intervals (CIs) of the GM faecal indicator organism (FIO) concentrations (cfu $100ml^{-1}$) 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)

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 x 108
Cow	230,000	23,600	5.4 x 109
Duck	33,000,000	336	1.1 x 1010
Horse	12,600	20,000	2.5 x 108
Pig	3,300,000	2,700	8.9 x 108
Sheep	16,000,000	1,130	1.8 x 1010
Turkey	290,000	448	1.3 x 108
Human	13,000,000	150	1.9 x 109

Source: (Gauthier & Bedard, 1986)

3. Statistical Data

One-way ANOVA: logec versus Season Oysters

```
Source DF SS MS F P
Season 3 1.079 0.360 3.23 0.031
Error 45 5.017 0.111
Total 48 6.096

S = 0.3339 R-Sq = 17.70% R-Sq(adj) = 12.22%

 Individual 95% CIs For Mean Based on
 Pooled StDev
Level N Mean StDev --------+---------+---------+---------+-
1 14 1.0215 0.0805 (--------*--------)
2 13 1.3885 0.5088 (--------*---------)
3 9 1.2349 0.4067 (----------*----------)
4 13 1.0769 0.2046 (--------*--------)
 --------+---------+---------+---------+-
 1.00 1.20 1.40 1.60

Pooled StDev = 0.3339

Grouping Information Using Tukey Method

Season N Mean Grouping
2 13 1.3885 A
3 9 1.2349 A B
4 13 1.0769 A B
1 14 1.0215 B

Means that do not share a letter are significantly different.


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Season

Individual confidence level = 98.94%

Season = 1 subtracted from:

Season Lower Center Upper ---------+---------+---------+---------+
2 0.0241 0.3670 0.7098 (--------*---------)
3 -0.1669 0.2134 0.5937 (----------*----------)
4 -0.2874 0.0554 0.3983 (---------*--------)
 ---------+---------+---------+---------+
 -0.35 0.00 0.35 0.70


Season = 2 subtracted from:

Season Lower Center Upper ---------+---------+---------+---------+
3 -0.5396 -0.1536 0.2324 (----------*----------)
4 -0.6607 -0.3115 0.0376 (---------*---------)
 ---------+---------+---------+---------+
 -0.35 0.00 0.35 0.70


Season = 3 subtracted from:

Season Lower Center Upper ---------+---------+---------+---------+
4 -0.5439 -0.1580 0.2280 (----------*-----------)
 ---------+---------+---------+---------+
 -0.35 0.00 0.35 0.70
```

One-way ANOVA: logec versus Season mussels

```
Source DF SS MS F P
Season 3 4.134 1.378 4.62 0.007
Error 42 12.522 0.298
Total 45 16.656

S = 0.5460 R-Sq = 24.82% R-Sq(adj) = 19.45%


 Individual 95% CIs For Mean Based on
 Pooled StDev
Level N Mean StDev --------+---------+---------+---------+-
1 15 1.0803 0.1378 (-------*-------)
2 10 1.6939 0.7392 (---------*---------)
3 10 1.6958 0.8598 (---------*---------)
4 11 1.1042 0.2618 (---------*--------)
 --------+---------+---------+---------+-
 1.05 1.40 1.75 2.10

Pooled StDev = 0.5460

Grouping Information Using Tukey Method

Season N Mean Grouping
3 10 1.6958 A
2 10 1.6939 A
4 11 1.1042 A B
1 15 1.0803 B

Means that do not share a letter are significantly different.

Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Season

Individual confidence level = 98.93%

Season = 1 subtracted from:

Season Lower Center Upper --------+---------+---------+---------+-
2 0.0178 0.6136 1.2094 (--------*-------)
3 0.0197 0.6156 1.2114 (--------*-------)
4 -0.5554 0.0239 0.6033 (-------*--------)
 --------+---------+---------+---------+-
 -0.70 0.00 0.70 1.40

Season = 2 subtracted from:

Season Lower Center Upper --------+---------+---------+---------+-
3 -0.6508 0.0019 0.6546 (--------*--------)
4 -1.2274 -0.5897 0.0479 (---------*--------)
 --------+---------+---------+---------+-
 -0.70 0.00 0.70 1.40

Season = 3 subtracted from:

Season Lower Center Upper --------+---------+---------+---------+-
4 -1.2293 -0.5916 0.0460 (---------*--------)
 --------+---------+---------+---------+-
 -0.70 0.00 0.70 1.40
```

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

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

Document Number	B_0067 Shoreline 0009
Revision	Issue 02
Date	06/06/2013

Revision History

Revision	Changes	Date
A	Issue for internal review	03/05/2013
01	First formal issue to CEFAS	09/05/2013
02	Revised issue to CEFAS resolving comments on revision 01	06/06/2013

	Name & Position	Date
Author	Andrea Veszelovszki	06/06/2013
Checked	John Hausrath	06/06/2013
Approved	John Hausrath	06/06/2013

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

Shoreline Survey Report

Production area:	Loch Eriboll Loch Eriboll Oysters
Site name:	Loch Eriboll – MacLennan Loch Eriboll – Mathers Loch Eriboll – McGowan Loch Eriboll Loch Eriboll Oysters – MacLennan Loch Eriboll Oysters
SIN:	Loch Eriboll – MacLennan HS-139-307-08 Loch Eriboll – Mathers HS-139-308-08 Loch Eriboll – McGowan HS -139-309-08 Loch Eriboll HS139-305-08 Loch Eriboll Oysters – MacLennan HS-139-307-13 Loch Eriboll Oysters HS-139-305-13
Species:	Mussels (*Mytilus edulis*) and Pacific Oyster (*Crassostrea gigas)*
Harvester:	Mr John Ross (mussels), Mr Mathers (oysters)
Local Authority:	Highland Council : Sutherland
Status:	Existing area
Date Surveyed:	8th to 10th April 2013
Surveyed by:	Lars Brunner, Debbie Brennan
Existing RMP:	Loch Eriboll NC 4189 5928 Loch Eriboll Oysters NC 4189 5928

Area Surveyed: Southern shore of Ard Neackie peninsula, then starting again at the shoreline immediately below Eriboll farm and heading SW to the head of the loch, finally following the western shoreline northwards to finish at Port Chamuill.

Weather

No precipitation over the preceding 48hrs of survey. The 2 months preceding the survey period had seen little rainfall over the survey area.

Mon 8th April: 15% cloud cover, wind speed 6.5 km/h gusting to 12.1 km/h (E), sea state calm, sunny, temperature of 3.9°C.

Tue 9th April: 30% cloud cover, wind speed 9.6km/h, gusting slightly (E), sea state calm, sunny alternating w. overcast, strong hail shower later, temperature of 4.1°C.

Wed 10th April: 20% cloud cover, increasing to 80%, wind speed 3.8km, rising

later with gusts (E). sea state calm, increasing with gusts.
sun with short hail showers, temperature of 4.6°C.

Stakeholder engagement during survey

Both the harvester and the local sampling officer were very helpful and cooperative during survey planning. Mr Alex Ross (brother of the local shellfish harvester Mr John Ross) met us on the morning of the 10th April with the intention of taking us to site on his boat. Due to problems with the vessel, we did not manage to access the loch.

Due to time constraints it was not possible to meet up with the local sampling officer during the survey.

Fishery

The fishery in Loch Eriboll consists of mussel and oyster cultivation. Much of the mussel cultivation in the loch is currently either disused or not being worked to its full potential. The locations currently leased by Mr Ross are shown in Fig. 3 and Fig. 4. These locations (mussel lines at Laid, WE1-WE6, and at An Druim, EE1-EE6) were supplied by the harvester following the survey. The locations provided correspond to that observed and noted by the team during the survey.

There are other small areas of line present in the Loch, but we were informed that these are all effectively abandoned.

The oyster fishery in the loch appears to be in a similar situation. The only evidence of any activity was at the RMP (NC 4189 5928) at which there were only 12 trestles present. On those trestles there were only two bags containing live oysters, and these bags were each only half full, so the total site contained the equivalent of one bag of live oysters. As it was not possible to access the loch on this survey due to boat problems, the shellfish sample (LESF1) was taken from these oysters.

Sewage Sources

The majority of the surveyed loch area has human activity present, although the population density is very low, and there are no major settlements within the loch's watershed. On the eastern shore of the loch there are no direct discharges onto the shore, and the only habitation consists of a small cluster of houses around the farm at Eriboll. There is one isolated house at the southern end of the loch, and then no habitation until the village of Laid, although no discharge pipes were seen on the shore here. The village does not have a public sewerage system. Finally, the group of houses around

Portnancon share a joint septic tank, which appears to have a run-off into the bay. No discharge pipe was noted at the fish farm base at Port Chamuill.

Seasonal Population

There are no campsites, caravan parks or hotels within the survey area. There is one B&B located in the village of Laid, and several self-catering properties split between Laid and Portnancon. It is assumed that there are some second homes within the area, although it was not possible to verify the number during the survey.

Boats/Shipping

Loch Eriboll has a mixture of small boat activity – there is workboat activity between the fish farm shore base at Port Chamuill and Kempie, and there is intermittent fishing (creeling) using small boats, as well as some recreational activity. Loch Eriboll has also been used intermittently in the past as a deep water anchorage for large vessels (i.e. the Royal Navy), although no such vessels were present during the survey.

There are two permanent piers within the survey area, the first at Ard Neackie, the second at Portnancon. Both of these are small stone piers that would only be of use at high tide. There are several sites around the loch where smaller boats have been hauled onto the shore, these most likely being for personal use.

Farming and Livestock

The shores around Loch Eriboll are largely used for rough grazing. During the survey the predominant livestock seen was sheep, although on the western side of the loch smaller crofts had a greater diversity of animals, and these included goats and ducks. Some cattle were seen at a farm along the main road in the village of Laid (while returning to our vehicle), but were not observed as part of the survey route.

Land Use

On the eastern shore of the loch the land is used for farming, the improved grassland around Eriboll farm rapidly giving way to rough grazing over the rest of the shoreline area. This usage pattern continues around the southern shore of the loch to the southern edge of the village of Dail. From here northwards the land usage changes to small scale crofting units, with a mix of agricultural and recreational usage. The land usage reverts again to rough grazing again north of Dail, with intermittent houses and the shore base for the fish farms at Port Chamuill.

Land Cover

As noted above, the land is almost all rough moorland and bog, with a small area of native woodland around Kempie and the SE corner of the bay. There is a larger area of plantation woodland to the SW corner of the bay. The lands surrounding Eriboll Farm and Ard Neackie consist of improved grassland, and several of the crofts in the village of Laid have small areas of improved grazing within their grounds.

Watercourses

The largest river entering the loch on the survey route is an unnamed river which discharges through Strath Beag into the SW corner of the loch at NC 3908 5470. All of the other watercourses encountered on the survey were much smaller than this, and were more akin to streams. All of the watercourses in the survey area had been affected by the long period of dry weather preceding the survey and several dry streams were noted.

Wildlife/Birds

Mallard ducks, eider ducks, gulls, oystercatchers and red-throated divers were seen at various points during the survey. No other wildlife was observed during the survey.

Shoreline Survey Maps

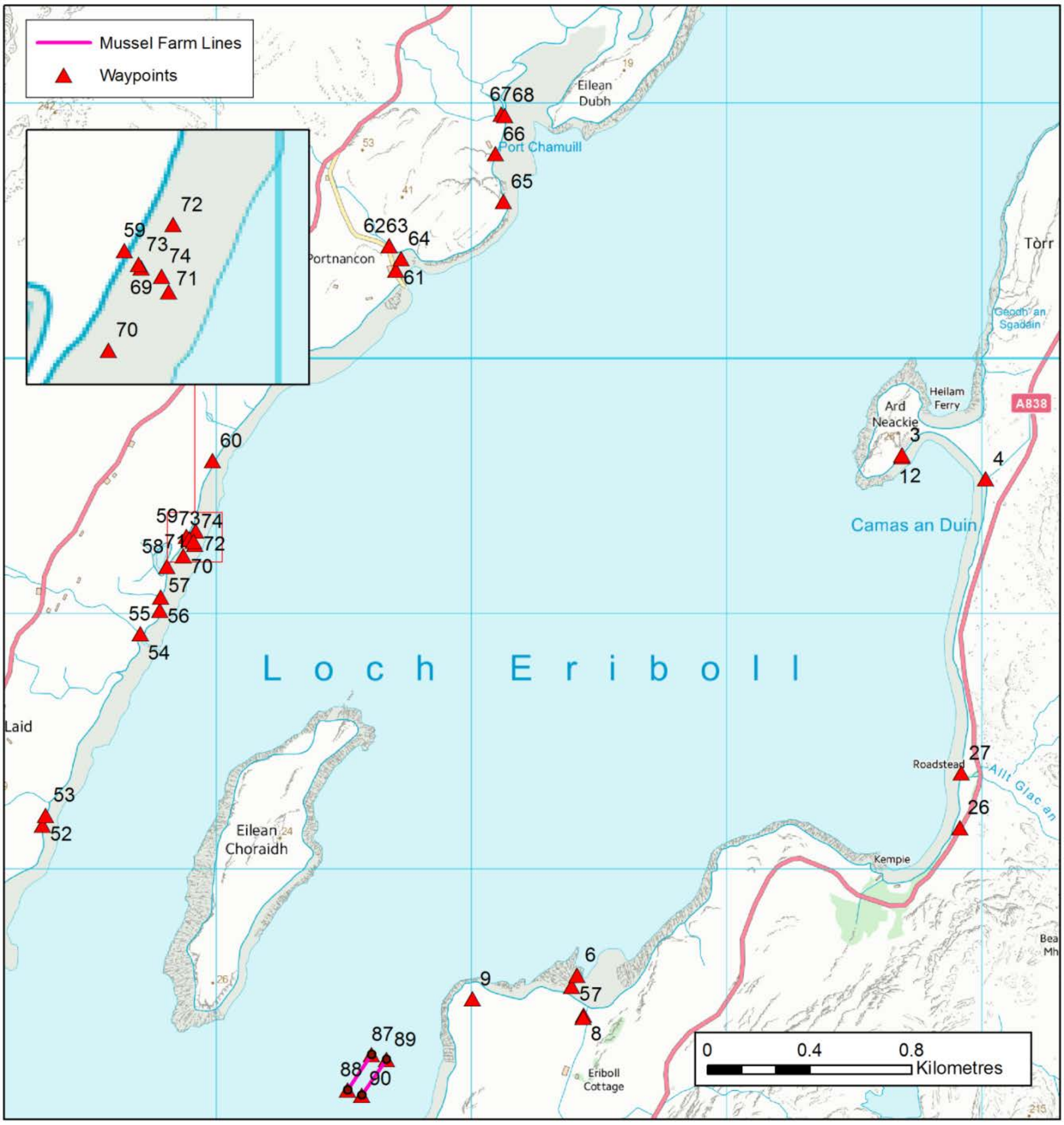
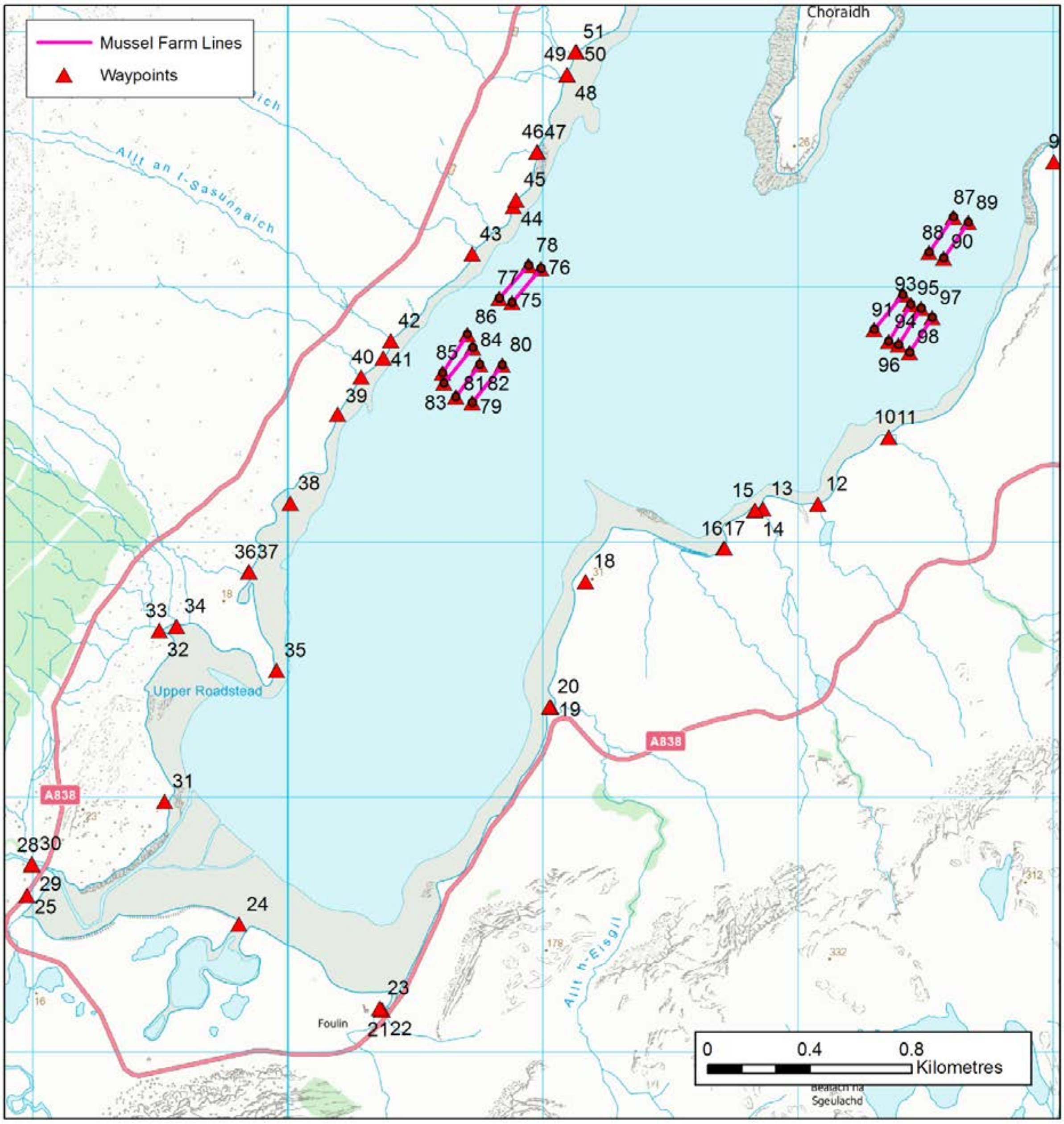


Figure 1. Loch Eriboll Waypoints (Upper Loch)



Contains Ordnance Survey data © Crown Copyright and Database right (2013)

Figure 2. Loch Eriboll Waypoints (Lower Loch)

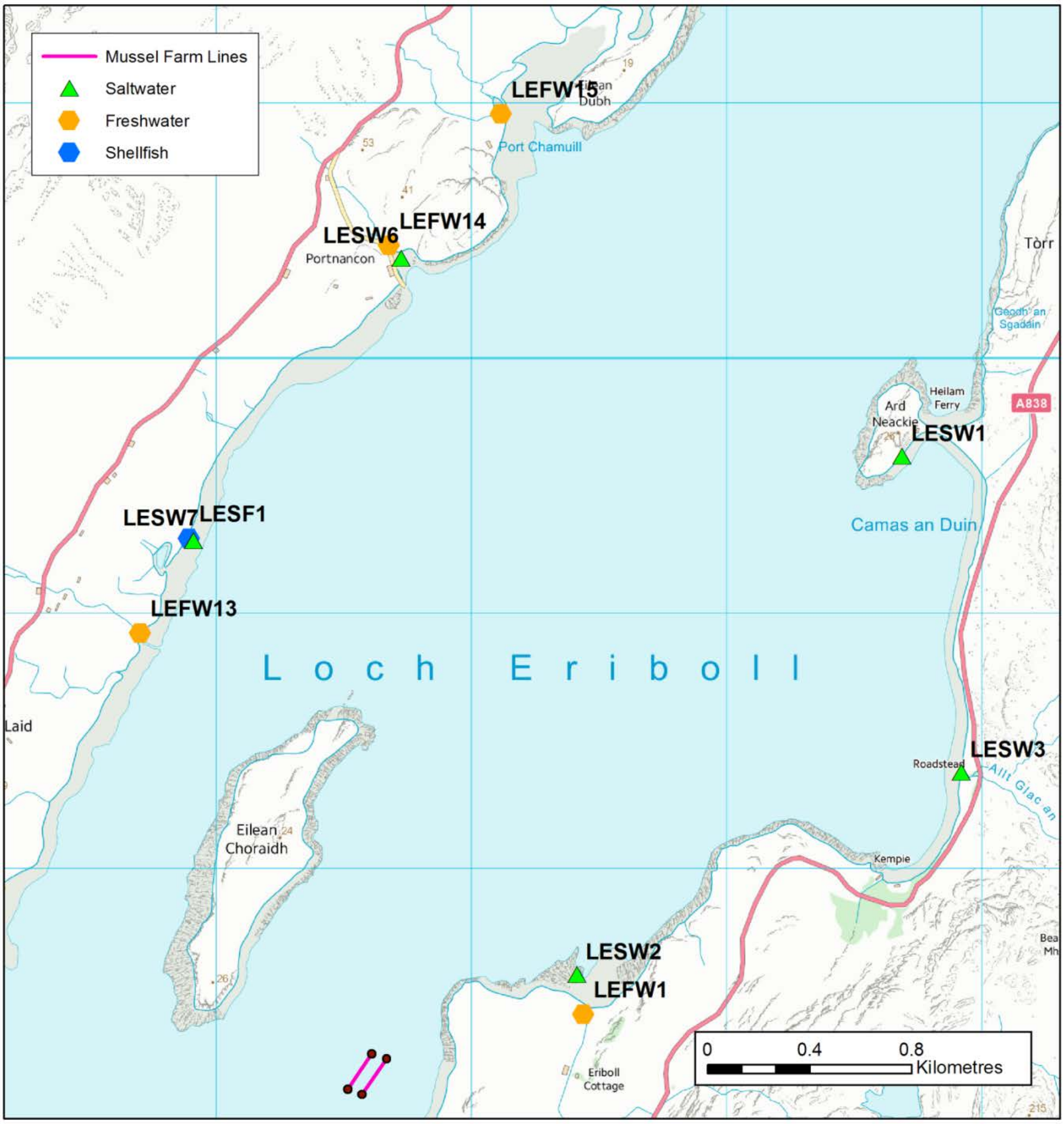


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Figure 3. Loch Eriboll Samples (Upper Loch)

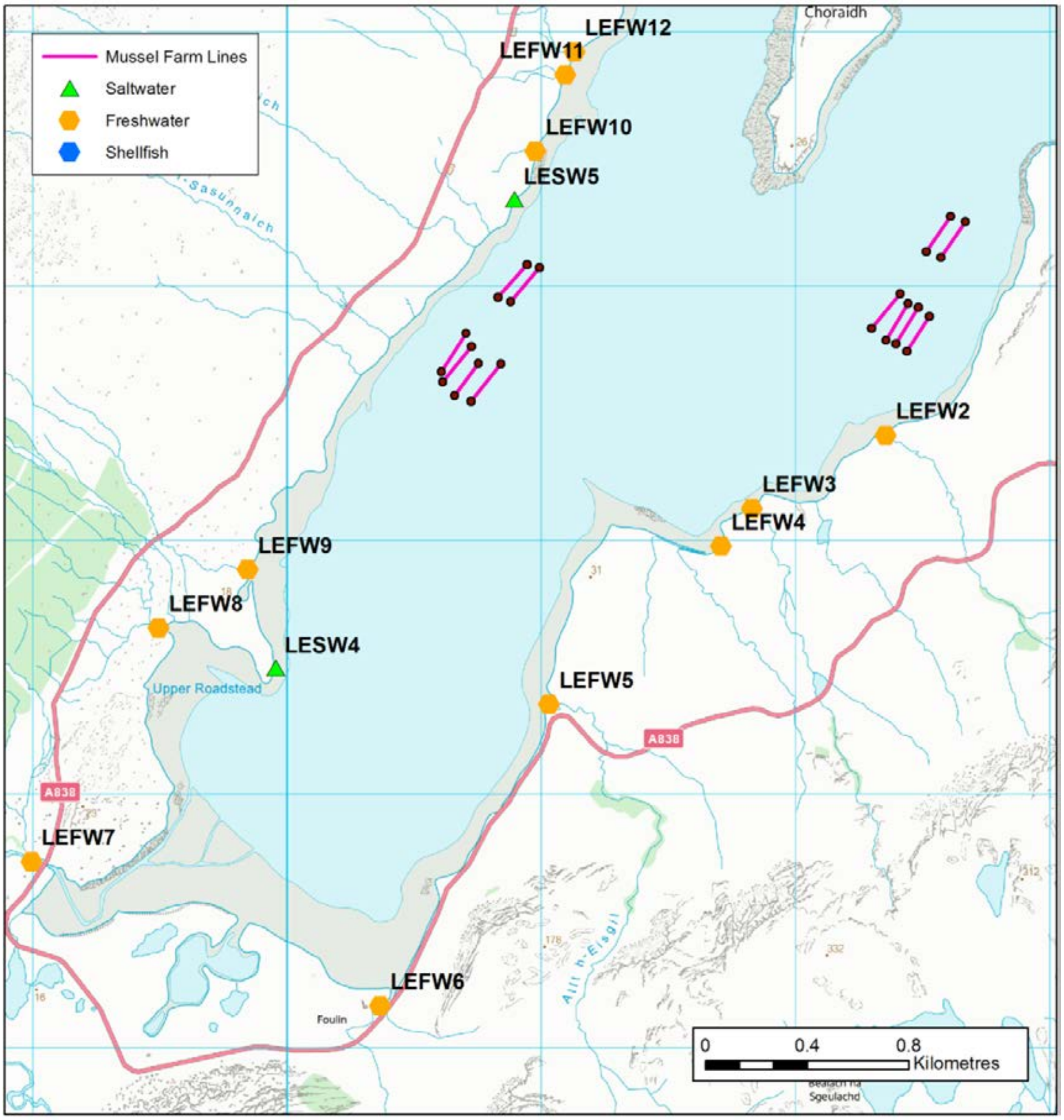

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Figure 4. Loch Eriboll Samples (Lower Loch)

Table 1 Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
1	08/04/2013	8:45	NC 44688 59615	244688	959616			Start of Survey.
2	08/04/2013	8:45	NC 44688 59615	244688	959616		LESW1	Seawater sample
3	08/04/2013	8:48	NC 44686 59622	244686	959622	Fig 5.		Photos of pier, old lime kiln (unused) and top end area of pier. Some buoys on pier, but no sign of recent activity. Birds: red throated diver, 2 oystercatchers, and 2 common sandpipers. Livestock in area of beach, approximately 40 sheep
4	08/04/2013	8:57	NC 45014 59528	245015	959529			End of truncated section of survey. Two small streams running to beach, both dry due to weather. Two static caravans at back of field, both appear unoccupied
5	08/04/2013	10:02	NC 43392 57540	243393	957541	Fig 6.		Start of next section of survey
6	08/04/2013	10:06	NC 43413 57584	243414	957585	Fig 6.	LESW2	Seawater sample
7	08/04/2013	10:10	NC 43439 57428	243440	957428		LEFW1	Freshwater sample - not marked as sample on map, but taken due to proximity of housing & livestock (approx. 80 sheep present). Sample associated with waypoint 8.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
8	08/04/2013	10:13	NC 43437 57418	243438	957419			Stream measurement: width 1.2m, depth 15cm, flow 0.036 m/s SD 0.006
9	08/04/2013	10:24	NC 43003 57491	243003	957491			Looking at the mussel farm sites - nothing visible in channel between Eilean Choraidh and E shore. Large area west of An Druim has six short lines, maximum length 100m each.
10	08/04/2013	10:53	NC 42355 56412	242356	956412		LEFW2	Freshwater sample. Sample associated with waypoint 11.
11	08/04/2013	10:56	NC 42355 56410	242356	956410			Stream measurement: width 1.1m, depth 5cm, flow 0.109m/s SD 0.003
12	08/04/2013	11:05	NC 42078 56149	242078	956150			Drystream bed, no flow (stream marked on map as NC 4207 5616)
13	08/04/2013	11:10	NC 41862 56130	241863	956131			Sheep count over upland area, this side of road, approximately 20 sheep
14	08/04/2013	11:14	NC 41830 56123	241830	956124		LEFW3	Freshwater sample. Sample associated with waypoint 15.
15	08/04/2013	11:14	NC 41830 56124	241831	956124			Stream measurement : width 60cm, depth 5cm, flow 0.232m/s SD 0.003
16	08/04/2013	11:24	NC 41708 55975	241709	955976		LEFW4	Freshwater sample. Sample associated with waypoint 17.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
17	08/04/2013	11:27	NC 41711 55975	241712	955976			Stream measurement : width 1.7m, depth 9cm, flow 0.049m/s SD 0.005
18	08/04/2013	11:41	NC 41166 55845	241167	955846	Fig 7.		In lower part of bay, E side, S end, photo of single mussel line set-up. 1 length, approx. 30m
19	08/04/2013	11:51	NC 41031 55352	241031	955353		LEFW5	Freshwater sample. Sample associated with waypoint 20.
20	08/04/2013	11:51	NC 41026 55354	241027	955355			Stream measurement : width 1.5m, depth 13cm, flow 0.144m/s SD 0.003
21	08/04/2013	12:20	NC 40367 54166	240368	954167		LEFW6	Freshwater sample (extra sample) Associated with waypoint 22.
22	08/04/2013	12:20	NC 40369 54165	240370	954165			Stream measurement : width 2m, depth 1 18cm flow 0.016m/s SD 0.003 depth 2 :22cm flow 0.001 m/s SD 0.003
23	08/04/2013	12:26	NC 40359 54173	240359	954173	Fig 8.		Sheep fold, no sheep present but looks like it has been used recently.
24	08/04/2013	12:49	NC 39807 54502	239807	954502			Outflow from two tidal lochs, not sampled as mixed saline and fresh and we have samples (fresh) from immediately to west and east, and seawater sample from just to the north.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
25	08/04/2013	13:07	NC 38976 54615	238976	954616			End of survey, day 1.
26	08/04/2013	13:21	NC 44914 58162	244914	958163			Site at Kempie - fish farm, 4 square cage set (salmon?). No sign at road end indicating ownership. Will collect seawater sample on day 2.
27	09/04/2013	8:43	NC 44919 58376	244919	958377		LESW3	Seawater sample (extra) LESW3. Related to fish farm above (waypoint 26)
28	09/04/2013	9:37	NC 38996 54734	238997	954734			Start of survey day 2.
29	09/04/2013	9:37	NC 38995 54733	238995	954734	Fig 9.	LEFW7	Freshwater sample. Sample associated with waypoint 30.
30	09/04/2013	9:41	NC 38996 54739	238996	954740	Fig 9.		River measurement: Width 8.4m; depth 1 22cm; flow 0.036 m/s SD 0.014; depth 2; 25cm, flow 0.374 m/s SD 0.012; depth 3; 25cm. Flow 0.201m/s SD 0.015. Only three measurements taken as wetted bank was too shallow for measurement. Connected to waypoint 29.
31	09/04/2013	9:58	NC 39516 54983	239516	954984			Bird count; 1 red throated diver, 4 oystercatcher
32	09/04/2013	10:11	NC 39495 55653	239495	955654		LEFW8	Freshwater sample. Sample associated with waypoint 33.
33	09/04/2013	10:12	NC 39496 55652	239496	955652			Stream measurement; width 2.9m; depth 1; 24cm, flow

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
								0.007m/s SD 0.004 depth 2; 12cm, flow 0.074 m/s SD 0.007. Connected to waypoint 32.
34	09/04/2013	10:20	NC 39562 55671	239563	955671			Small stream flowing into bay adjacent to stream sampled in waypoint 32. Not sampled.
35	09/04/2013	10:30	NC 39955 55497	239956	955498		LESW4	Seawater sample
36	09/04/2013	10:38	NC 39847 55883	239847	955884		LEFW9	Freshwater sample (NC 3984 5588) Sample associated with waypoint 37.
37	09/04/2013	10:43	NC 39848 55883	239849	955884			Stream measurement; width 2.1m, depth 19cm, flow 0.083 m/s SD 0.019.
38	09/04/2013	10:55	NC 40009 56152	240010	956152			Start of longline section offshore in Loch. One small clump (around 20m in length) and then isolated buoys running north
39	09/04/2013	11:04	NC 40195 56502	240195	956503			Ten sheep on hillside
40	09/04/2013	11:08	NC 40287 56646	240288	956647			Very small stream running off hillside - not sampled
41	09/04/2013	11:10	NC 40373 56722	240373	956722			Start of larger longline section offshore in Loch. 4+ sets of 100m+ lines

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
42	09/04/2013	11:14	NC 40403 56789	240403	956789			Very small stream running off hillside - not sampled as practically dry
43	09/04/2013	11:22	NC 40723 57129	240723	957130			Six sheep present on hillside, 4 oystercatchers on shore. End of extended mussel line section offshore in Loch. No sign of annotated stream (NC 4071 5715), but dried up stream bed present.
44	09/04/2013	11:31	NC 40883 57315	240884	957316	Fig 10.		Run of stones down to shore that looks like cover for a discharge pipe. On closer inspection, no sign of any pipe and looks like boundary wall on shoreline.
45	09/04/2013	11:40	NC 40895 57341	240895	957342		LESW5	Extra seawater sample taken in case waypoint 44 is actually a discharge pipe.
46	09/04/2013	11:46	NC 40978 57530	240979	957530	Fig 11.	LEFW10	Freshwater sample (extra sample due to houses on hillside above). Sample associated with waypoint 47.
47	09/04/2013	11:48	NC 40975 57529	240975	957529			Stream measurement; width 70cm; depth 31cm; flow 0.014 m/s SD 0.003.
48	09/04/2013	11:59	NC 41095 57831	241095	957832		LEFW11	Freshwater sample. Sample associated with waypoint 49.
49	09/04/2013	11:59	NC 41094 57833	241095	957833			Stream measurement; width 1.2m; depth 10cm; flow 0.031

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
								m/s SD 0.004
50	09/04/2013	12:08	NC 41132 57922	241133	957922		LEFW12	Freshwater sample (extra) taken due to presence of animals on croft on hillside above (10 sheep, 8 goats, 15-20 ducks). Sample associated with waypoint 51.
51	09/04/2013	12:09	NC 41126 57922	241127	957922			Stream measurement; width 1.6m, depth 7cm, flow 0.002m/s SD 0.004.
52	09/04/2013	12:28	NC 41317 58172	241318	958173	Fig 12.		Site of activity (or previous activity) on shore - mussel buoys and hauled up boats. End of Survey, day 2.
53	10/04/2013	10:31	NC 41330 58211	241331	958211			Start of survey, day 3.
54	10/04/2013	10:43	NC 41702 58922	241703	958922		LEFW13	Freshwater sample. Sample associated to waypoint 55.
55	10/04/2013	10:44	NC 41701 58921	241702	958922			Stream measurement; width 2.6m; depth 1; 27cm; flow 0.021 m/s SD 0.003 depth 2; 29cm, flow 0.018 m/s.
56	10/04/2013	10:52	NC 41778 59014	241778	959014			Start of offshore section of mussel line. Seven eider duck recorded.
57	10/04/2013	10:55	NC 41781 59065	241782	959066			Drystream bed, no flow.
58	10/04/2013	10:57	NC 41806 59185	241807	959185			Pipe at top of beach, overflow pipe for tidal pond behind.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
								Dry.
59	10/04/2013	11:01	NC 41882 59304	241882	959304			Location of RMP - tide too high to observe trestles or sample (returned later)
60	10/04/2013	11:08	NC 41985 59599	241986	959600			End of offshore section of mussel line
61	10/04/2013	11:23	NC 42703 60347	242704	960347	Fig 13.		Septic tanks for holiday cottages at Portnancon Pier
62	10/04/2013	11:26	NC 42677 60441	242678	960442		LEFW14	Freshwater sample. Sample associated to waypoint 63.
63	10/04/2013	11:27	NC 42678 60441	242678	960442			Stream measurement; width 2.2m, depth 14cm; flow 0.031 m/s SD 0.013.
64	10/04/2013	11:34	NC 42723 60391	242724	960392		LESW6	Seawater sample.
65	10/04/2013	11:47	NC 43125 60615	243125	960615	Fig 14.		Photo of Fish farm shore base at Port Chamuill.
66	10/04/2013	11:54	NC 43094 60803	243095	960804			Dry land drain at fish farm base.
67	10/04/2013	12:01	NC 43117 60957	243117	960957		LEFW15	Freshwater sample. Sample associated to waypoint 68.
68	10/04/2013	12:02	NC 43131 60953	243131	960953			Stream measurement; width 1.2m; depth 13cm, flow 0.096 m/s 0.007 SD.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
69	10/04/2013	12:39	NC 41895 59290	241895	959291	Fig 15.		Return to RMP site and oyster trestles at low tide. Harvester not present. 11 trestles, with few bags. Only two bags had any live oysters inside - sampled a mix between the 2 bags.
70	10/04/2013	12:45	NC 41870 59227	241870	959228			Corner of trestles
71	10/04/2013	12:51	NC 41916 59272	241916	959273			Corner of trestles
72	10/04/2013	12:53	NC 41919 59323	241920	959324			Corner of trestles
73	10/04/2013	12:55	NC 41892 59293	241893	959294		LESF1	Shellfish sample (Pacific oyster)
74	10/04/2013	12:58	NC 41910 59284	241911	959285		LESW7	Seawater sample.
75			NC 40878 56939	240879	956939			Harverster supplied data: Mussel line locations - Laid - Line WE1
76			NC 40992 57072	240992	957073			Mussel line locations - Laid - WE1
77			NC 40829 56957	240829	956957			Mussel line locations - Laid - WE2
78			NC 40943 57085	240944	957086			Mussel line locations - Laid - WE2
79			NC 40723 56546	240723	956547			Mussel line locations - Laid - WE3

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
80			NC 40840 56695	240840	956695			Mussel line locations - Laid - WE3
81			NC 40658 56568	240659	956569			Mussel line locations - Laid - WE4
82			NC 40752 56696	240752	956696			Mussel line locations - Laid - WE4
83			NC 40610 56623	240611	956624			Mussel line locations - Laid - WE5
84			NC 40725 56761	240725	956762			Mussel line locations - Laid - WE5
85			NC 40606 56663	240607	956664			Mussel line locations - Laid - WE6
86			NC 40703 56814	240703	956814			Mussel line locations - Laid - WE6
87			NC 42608 57274	242609	957274			Mussel line locations - An Druim - EE1
88			NC 42514 57135	242514	957135			Mussel line locations - An Druim - EE1
89			NC 42667 57253	242667	957253			Mussel line locations - An Druim - EE2
90			NC 42570 57112	242571	957113			Mussel line locations - An Druim - EE2
91			NC 42297 56832	242298	956833			Mussel line locations - An Druim - EE3

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
92			NC 42411 56970	242412	956970			Mussel line locations - An Druim - EE3
93			NC 42442 56932	242442	956932			Mussel line locations - An Druim - EE4
94			NC 42355 56785	242356	956786			Mussel line locations - An Druim - EE4
95			NC 42482 56917	242483	956917			Mussel line locations - An Druim - EE5
96			NC 42393 56771	242394	956772			Mussel line locations - An Druim - EE5
97			NC 42526 56880	242527	956880			Mussel line locations - An Druim - EE6
98			NC 42437 56743	242437	956744			Mussel line locations - An Druim - EE6

Photographs referenced in the table can be found attached as Figures 5 - 15

Sampling

Water samples were collected at sites marked on the map shown in Figures 3 and 4. Samples were transferred to Biotherm 10 boxes with ice packs and shipped to Glasgow Scientific Services (GSS) for *E.coli* analysis. All samples were shipped on the day of collection from Lairg post office. All except the samples on the 8th April were received and analysed the following day. The samples sent from Lairg on the 8th were delivered incorrectly to SAMS the following morning (by error of the Post Office), but were hand-delivered to GSS on the same day. The sample temperatures on arrival to the laboratory ranged between 4.3°C and 6.5°C.

Seawater samples were tested for salinity by GSS and the results 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	08/04/13	LESW1	NC 44686 59622	Seawater	0	35.5
2	08/04/13	LESW2	NC 43439 57428	Seawater	0	35.4
3	08/04/13	LEFW1	NC 43437 57418	Freshwater	<100	
4	08/04/13	LEFW2	NC 42355 56410	Freshwater	<100	
5	08/04/13	LEFW3	NC 41830 56124	Freshwater	<100	
6	08/04/13	LEFW4	NC 41711 55975	Freshwater	<100	
7	08/04/13	LEFW5	NC 41026 55354	Freshwater	<100	
8	08/04/13	LEFW6	NC 40369 54165	Freshwater	<100	
9	09/04/13	LESW3	NC 44899 58375	Seawater	0	35.7
10	09/04/13	LEFW7	NC 38996 54739	Freshwater	<100	
11	09/04/13	LEFW8	NC 39496 55652	Freshwater	<100	
12	09/04/13	LESW4	NC 39949 55540	Seawater	0	34.7
13	09/04/13	LEFW9	NC 39848 55883	Freshwater	<100	
14	09/04/13	LESW5	NC 40978 57530	Seawater	0	33.1
15	09/04/13	LEFW10	NC 41095 57831	Freshwater	<100	
16	09/04/13	LEFW11	NC 41094 57833	Freshwater	<100	
17	09/04/13	LEFW12	NC 41126 57922	Freshwater	<100	
18	10/04/13	LEFW13	NC 41701 58921	Freshwater	<100	
19	10/04/13	LEFW14	NC 42678 60441	Freshwater	<100	
20	10/04/13	LESW6	NC 42738 60403	Seawater	0	33.2
21	10/04/13	LEFW15	NC 43131 60953	Freshwater	<100	
22	10/04/13	LESW7	NC 41910 59284	Seawater	0	36.1

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	*E. coli* (MPN/100g)
1	10/04/13	LESF1	NC 41910 59284	Pacific Oyster	<20

Photographs

Figure 5: Ard Neackie and pier (waypoint 3), with disused lime kilns. Looking SW.

Figure 6: Beach and stream below Eriboll Farm. Location of waypoints 5 and 6 and associated samples. Ard Neackie peninsula is visible in centre distance of photo.

Figure 7: Overview of lower Loch Eriboll, taken from waypoint 18.

Figure 8: Sheep fold at waypoint 23.

Figure 9: Waypoints 29 and 30. Un-named River flowing under A838 road overbridge. The largest watercourse on survey.

Figure 10: Stone run on shore, initially mistaken for cover for a discharge pipe, but actually shoreline boundary walls for crofts above (waypoint 44).

Figure 11: Typical croft style housing in the village of Laid. Photo taken from the shore around waypoint 46.

Figure 12: Typical shoreline on W shore of Loch below the village of Laid, with small housing, boat huts and beached boats and material (waypoint 52).

Figure 13: Holiday homes and Pier at Portnancon, with septic tanks enclosed in wooden cage (waypoint 61).

Figure 14: Fish farm base at Port Chamuill, taken from the south (waypoint 65).

Figure 15: Oyster trestles at the RMP (waypoint 69). Site is largely empty and abandoned.