Scottish Sanitary Survey Report

Sanitary Survey Report
Loch Glencoul
HS-157-310-08
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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 mussel fishery at Loch Glencoul 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 Glencoul is on the north-west of Scotland, east of Eddrachillis Bay. The production area actually lies within Loch Glendhu (Loch Gleann Dubh), which runs east from Caolas Cumhann at Kylesku.

The Loch Glencoul fishery consists of a single, long-line, common mussel (*Mytilus edulis*) farm which has been in production since 2002.

The principal sources of faecal contamination to the fishery are:

- Diffuse faecal contamination carried via watercourses Maldie Burn, Allt Briste, and an unnamed watercourse.
- Diffuse contamination from wildlife sources (seals and seabirds) at or near the fishery.

The hydrographic assessment showed that contaminants may be carried up to 1 km from sources along the axis of the loch to the fishery. Therefore, only sources in relatively close proximity to the fishery are likely to significantly contribute to faecal contamination levels found there.

it is recommended that the production area boundaries be curtailed to exclude areas to the south around the settlements of Kylesku and Unapool, where there are septic tank discharges. It is also recommended that the eastern boundary be curtailed to

exclude the mouth of Maldie Burn. The recommended RMP is at NC 2412 3419, which lies near the mouth of Allt Briste, north of the current nominal RMP.

II. Sampling Plan

Production Area	Loch Glencoul
Site Name	Kylesku
SIN	HS-157-310-08
Species	Common mussel
Type of Fishery	Long-line aquaculture
NGR of RMP	NC 2412 3419
East	224120
North	934190
Tolerance (m)	40
Depth (m)	1
Method of Sampling	Hand
Frequency of Sampling	Monthly
Local Authority	Highland Council - Sutherland
Authorised Sampler(s)	Anne Grant
Local Authority Liaison Officer	Alan Yates
Production Area	Area bounded by lines drawn from NC 2340 3450 to NC 2363 3352 to NC 2439 3310 to NC 2462 3391 and back to NC 2340 3450, extending to MHWS along the northern boundary

III. Report

1. General Description

Loch Glencoul is on the north-west of Scotland, east of Eddrachillis Bay. The production area actually lies within Loch Glendhu (Loch Gleann Dubh), which runs east from a strait (Caolas Cumhann) at Kylesku. Loch Glencoul itself branches south from Loch Glendhu, close to the strait. Collectively, the two form part of Loch Cairnbawn (Loch a' Chàirn Bhàin). The area is situated in the local authority district of Highland Council: Sutherland.

Loch Glendhu is approximately 4.5 kilometers in length with Loch Glencoul around 5 kilometers. Both Lochs are fjordic in origin with characteristic steep sides along much of their length.

The area is sparsely populated but there are small number of settlements close to the mouths of Loch Glendhu and Loch Glencoul.

Figure 1.1 Location of Loch Glencoul

2. Fishery

The Loch Glencoul fishery consists of a single, long-line, common mussel (*Mytilus edulis*) farm which has been in production since 2002. Details of the site are presented in Table 2.1.

Table 2.1 Area shellfish farms

Production area	Site	SIN	Species	RMP
Loch Glencoul	Kylesku	HS-157-310-08	Common Mussels	NC 2407 3406

The current production area encompasses the area bounded by lines drawn between NC 2330 3364 and NC 2340 3450 and between NC 2500 3395 and NC 2443 3314 and between NC 2571 3176 and NC 2500 3097

At the time of the shoreline survey mussels were grown in suspended culture on long-lines, to a depth of between 6-8 m. The sampling officer and harvester identified that harvesting may occur at any time of year. The harvester also supplied the boundaries of the farm depicted in Figure 2.1.

A second set of four 300 m longlines were observed during the shoreline survey near the head of the loch. The exact location of this was not taken at the time. Planning information on the site was available from the Highland Council e-Planning portal (Planning application reference 12/04804/FUL, receipt date 19/12/2012. http://www.highland.gov.uk/yourenvironment/planning/planningapplications/ViewworkcommentonaPlanningApplication.htm. Accessed 05/09/2013). The application was granted for the installation 4 x 300 m longlines for collection of mussel seed (spat), at the approximate location shown in Figure 2.1. This location is approximately 300 m beyond the SW boundary of the production area.

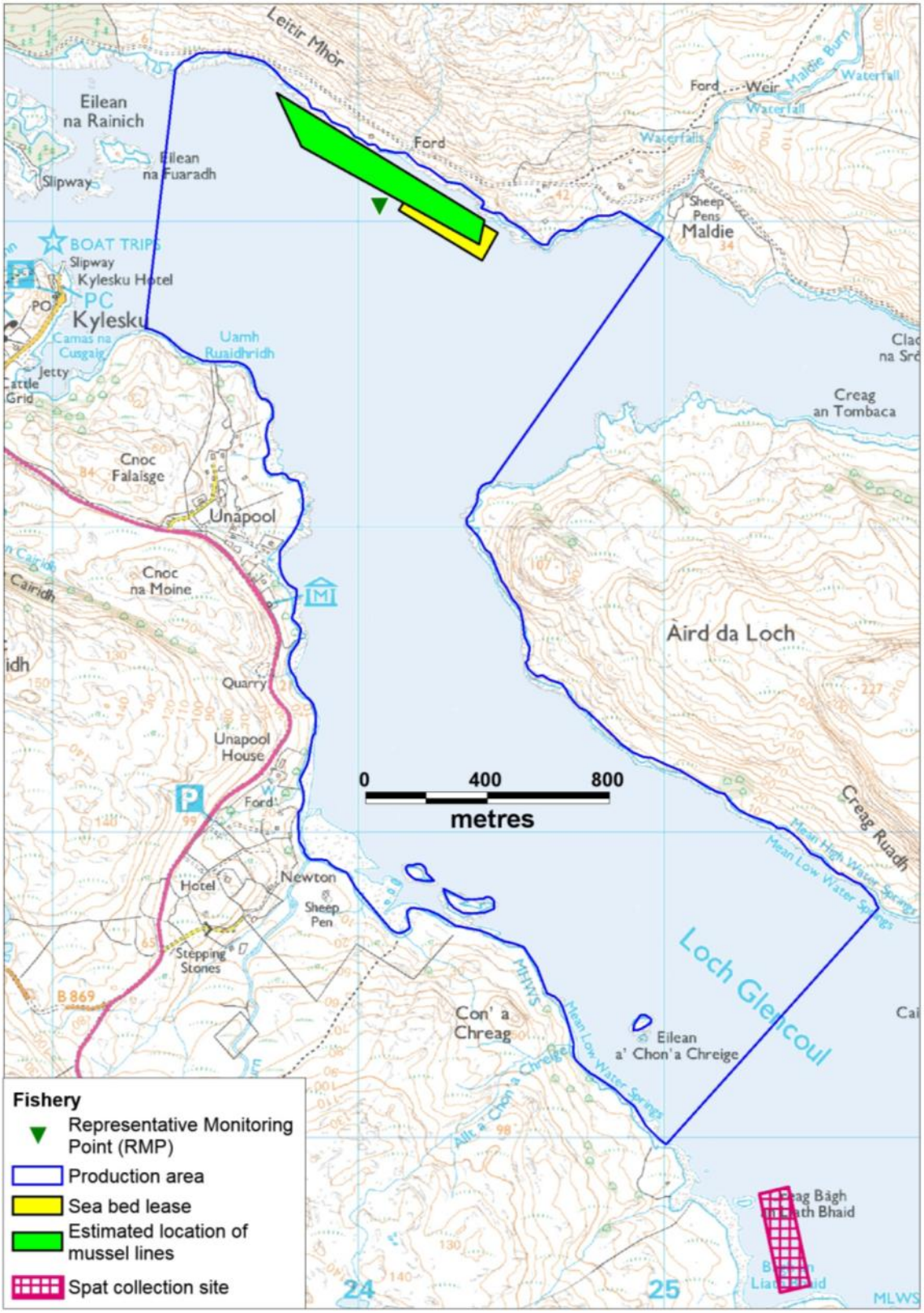

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Figure 2.1 Loch Glencoul Fishery

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 Glencoul. The last census was undertaken in 2011. Figure 3.1 shows a thematic map of the 2011 population density of the census output areas surrounding Loch Glencoul.

There are several small settlements (Kylesku, Unapool and Newton) located at the far eastern end of Loch Glendhu and Loch Glencoul. Each settlement is comprised of fewer than a dozen dwellings. The only area of coastline along Loch Glendhu and Loch Glencoul that is accessible by car is the stretch between Newton in the south to Kylesku in the north where the road continues north west over the Kylesku Bridge. Tourist accommodation in the area includes a hotel in Kylesku that can accommodate 16 people; ten self catering lodges near Unapool that can each accommodate 4 people; a bed and breakfast at Newton that can accommodate 14 people. The lodges are only let from May to September (http://www.kyleskulodges.co.uk/rates.htm, Accessed 05/09/2013).

The Clyde Cruising Club Guide identified anchorages in the area, which are marked in Figure 3.1 (Clyde Cruising Club, 2006). The northernmost of these lies approximately 800 m west of the mussel farm. Three jetties or slipways were observed during the shoreline survey, the locations of those recorded are shown in Figure 3.1. These are used mostly by boats working on the mussel lines, tourist boats and pleasure fishing vessels. On the day of the shoreline survey, there was one pleasure fishing boat close to Kylesku slipway.

Overall, the presence of tourist accommodation in the area indicates that impacts from human sources to the water quality of the shellfish bed are likely to be seasonal, peaking during the summer months when visitor numbers are higher.

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

4. Sewage Discharges

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

SEPA did not provide consent details related to the Scottish Water discharges and these were also not referred to in the Loch Glendhu shellfish growing water report (SEPA, 2011). The information could therefore not be cross-checked between sources.

Scottish Water Discharges

Scottish Water provided information of two septic tanks which are listed in Table 4.1 and are plotted in Figure 4.1. The "Unapool WWTW 1970" discharge serves two houses. The PE was given as <10. No PE was given for the "Kylesku chalets WWTW" discharge. Assuming the WWTW serves the 10 chalets visible on satellite imagery, the total connected population at peak occupancy would be 40 based on each chalet accommodating 4 people (Kylesku Lodges, 2013). As the chalets are only let out from May to September, there is only likely to be flow from the tank during these months. No information on discharge destination was given. For further assessment, this will be assumed to be identified by the geographical location. Kylesku Chalets discharges on the western side the headland on which Kylesku is situated, around 1.7 km from the mussel farm.

Unapool WWTW discharges to an unnamed watercourse feeding into the small inlet of Camas na Cusgaig on the eastern side of the Kylesku headland, 1.2 km from the mussel farm.

No CSOs or EOs are present in the area.

Table 4.1 Scottish Water Sewage Discharges

Discharge Name	Discharge Licence	NGR of discharge	Level of Treatment	PE
KYLESKU CHALETS WWTW 1970	T/B13/046/91(00)	NC 224 334	Septic Tank	-
UNAPOOL WWTW 1970	-	NC 230 337	Septic Tank	<10

- No data provided

SEPA discharge consents

SEPA provided information on 28 consents, 18 of which were for private sewage discharges. Of the remaining: 2 were consents for marine cage fish farms located in Loch a' Chàirn Bhàin to the west of the production area; 4 were consents for engineering works for the Maldie Burn hydroelectric power plant; and 4 were consents for water abstraction. The latter were not considered further.

There has not historically been a requirement in Scotland to register private septic tanks, and therefore only those houses which have registered their septic tanks with SEPA have been listed.

SEPA have noted that in some cases, septic tanks identified as discharging to soakaway may actually discharge to watercourses due to failure of the soakaway field and subsequent redirection by the homeowner. There are also likely to be a number of unregistered private discharges in the area, largely around the main centres of population.

Three of the private sewage discharges entered Loch a' Chàirn Bhàin significant distances (4 to 6 km) to the west of Caolas Cumhann: given the small size of these discharges, they have not been included in the map shown in Figure 4.1. Of the remaining private sewage discharges, one was identified as going directly to Loch Glencoul, ten to soakaway, and one to an unnamed watercourse which feeds into Loch Glendhu, For the remaining four, the receiving body for effluent was not stated. The details given for the private sewage discharge consents and the marine cage fish farms are listed in Table 4.2. Those not shown on the map in Figure 4.1 due to their distance from the mussel fishery are shown in grey in the table.

Table 4.2 Private discharge consents

Licence Number	National Grid Reference	Site Name	DPE	Discharge Type	Discharge To
CAR/R/1011595	NC 23560 33180	Camarnaloch, 372 Unapool, Kylesku	5	ST	Soakaway
CAR/R/1011602	NC 23660 31710	Newton, 573 Newton, Kylesku	5	ST	Soakaway
CAR/R/1012026	NC 23570 33130	Croft 375 & Camarnaloch Cott, Unapool Kylesku	11	ST	Soakaway
CAR/R/1012615	NC 22852 33403	An Acarsaid, Kylesku	5	ST	Unnamed Watercourse to Loch Glendhu
CAR/R/1017200	NC 23750 32220	Unapool House, Kylesku, Lairg	10	ST	Soakaway
CAR/R/1017421	NC 23385 33021	Ardaloch, Unapool Croft Road, Kylesku	5	ST	-
CAR/R/1040296	NC 23770 32000	Bungalow, 575 Newton, Kylesku, Lairg	5	ST	Soakaway
CAR/R/1058657	NC 23691 32812	371 Unapool, Kylesku, Sutherland + 373 Unapool	5	ST	-
CAR/R/1060555	NC 23700 32860	Glencoul Cottage, 373 Unapool, Kylesku	5	ST	Loch Glencoul
CAR/R/1067288	NC 23713 32945	Lag Na Feidh, 373 Unapool, Kylesku, Lairg	5	ST	-
CAR/R/1068419	NC 23595 32995	Fair Haven, 373 Unapool, Kylesku, Lairg	5	ST	-
CAR/R/1077483	NC 23576 31875	Newton Lodge, Kylesku, Sutherland	20	ST	Soakaway
CAR/R/1077531	NC 23520 33150	374 Unapool, Kylesku, Sutherland	5	ST	Soakaway
CAR/R/1098074	NC 22190 34720	Site Compound, Reay Forest Est, Kylestrome	15	ST	Soakaway
CAR/R/1098987	NC 25100 34030	BAM Nuttall Construction Compound, Kylestrome	9	ST	Soakaway
CAR/R/1065392	NC 19989 37389	Duartmore Hatchery, Duartmore, Scourie, Lairg	5	ST	Allt nah Airbhe
CAR/R/1065483	NC 19959 37397	Forestry Cottage, Duartmore, Scourie, Lairg	5	-	-
CAR/R/1036927	NC 19407 33331	Rientraid, Kylesku, Lairg	5	-	-
CAR/L/1001827	NC 20300 33200	Torgawn MCFF, Loch a Chairn Bhain	N/A	-	-
CAR/L/1002919	NC 19505 33610	Reintraid MCFF, Loch A Chairn Bhain	N/A	-	-

ST=Septic tank - = No data provided Not shown on map N/A= Not applicable

Shoreline Survey Discharge Observations

Six observations of possible sewage infrastructure were noted during the shoreline surveys. These are listed in Table 4.3 below.

Table 4.3 Discharge-associated observations made during the shoreline survey

No.	Date	Associated photograph	*E. coli* cfu/100ml	Description
1	09/07/2013	Appendix 5; Fig 4		Manhole covers beside public toilet, pipe running over rocks directly into loch. Strong sewage smell.
2	09/07/2013	-	>10000	Seawater sample taken close to outflow pipe; sample associated with observation 1.
3	09/07/2013	-		Clay pipe, diameter 20cm, pipe submerged so no indication of flow.
4	09/07/2013			Man hole cover above the shore, pipe running from it under cement covering into loch, not possible to access and sample.
5	09/07/2013	Appendix 5; Fig 5		Pipe protruding from under the road onto shore. Historical evidence of flow, i.e. staining below outflow but no obvious outflow at time of survey. Unable to access.
6	09/07/2013	Appendix 5; Fig 6		Pipe on shore, no access, appeared not to be in use.

Observation 1 reports a public toilet with outflow pipe into the loch. A strong smell of sewage was reported at this location. A sea water sample taken at the end of the outflow pipe (Observation 2) returned an extremely high *E. coli* result of >10000 cfu/100ml, the upper limit of detection for the method used The flow for this discharge was unable to be measured during the survey. This discharge does not correspond to any reported by SEPA or Scottish Water.

Observation 3 and 4 both report potential sewage discharge pipes. No flow was noted on observation 3 and it was unable to be ascertained on observation 4.

Observation 5 reports a pipe emerging from under the road. There was no flow at the time of the survey, but there is evidence of previous flow. This outfall corresponds approximately with Unapool WWTW.

Observation 6 reports a pipe on the shore. Although the surveyors were unable to access the end of the pipe at the time of survey the pipe did not appear to be in use.

Summary

The area around the production area is sparsely inhabited, and this is reflected in the small number of sewage discharges identified by SW/SEPA.

The closest discharge to the production area is a septic tank outfall to soakaway for BAM Nuttall construction compound located approximately 700 m east of the mussel farm. If the soakaway is operating correctly, the discharge should not contribute to contamination at the mussel farm.

Three registered discharges are reported around the Kylesku headland, the two public WWTWs and one private consent discharge to freshwater. Only one of the public WWTWs (Unapool WWTW) and the private consent discharge on the eastern side of the headland, the side closest to the mussel farm. The majority of private discharges are located south of the mussel farm, eight around Unapool, and four further south around Newton.

All six discharge observations from the shoreline survey were located on the tip of Kylesku headland around Kylesku. The only active discharge that was observed was associated with the public toilets at Kylesku. A seawater sample taken nearby returned a high value of >10000 *E. coli* cfu/100ml The main potential impact from human faecal sources is therefore associated with the discharges in the vicinity of Kylesku, approximately 1 km southwest of the mussel farm.

List of Acronyms

CSO	Combined Sewage Overflow	PS	Pumping Station
DWF	Dry weather flow	ST	Septic Tank
EO	Emergency Overflow	WWPS	Wastewater Pumping Station
FE	Final Effluent	WWTW	Wastewater Treatment Work
PE	Population Equivalent		

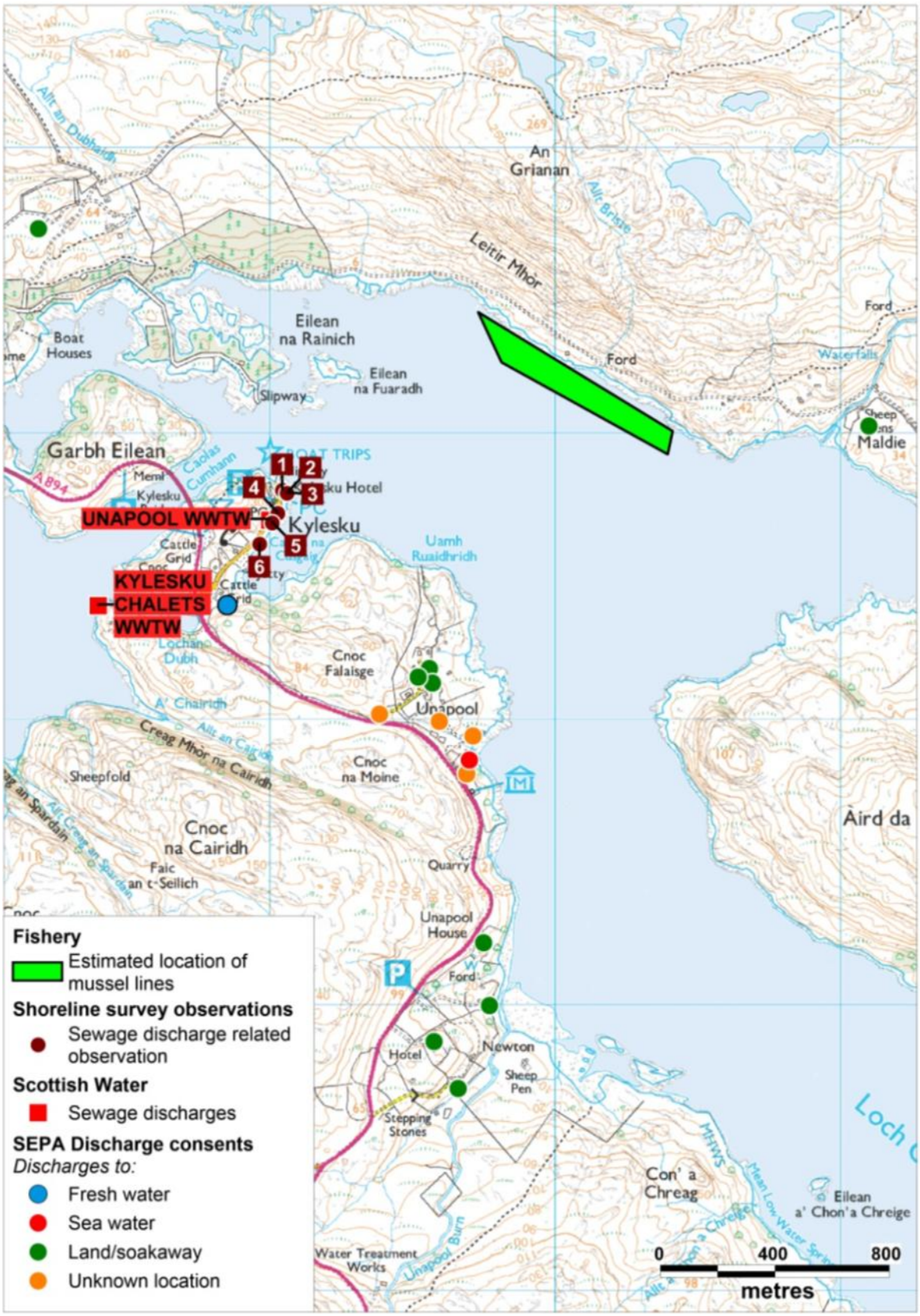


Figure 4.1 Map of discharges for Loch Glencoul

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. Agricultural census data to parish level was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for the Eddrachilles and Assynt parishes. Reported livestock populations for the parishes in 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 in the Eddrachilles and Assynt agricultural parishes 2012

	Eddrachilles		Assynt	
	575 km^2		474 km^2	
	Holdings	Numbers	Holdings	Numbers
Pigs	*	*	5	27
Poultry	10	122	26	389
Cattle	9	177	24	286
Sheep	44	5,222	65	5,648
Other horses and ponies	*	*	6	10

The livestock census numbers relate to very large parish areas, therefore it is not possible to determine the spatial distribution of the livestock in relation to the Loch Glencoul area or identify how many animals are likely to impact the catchment around the fishery. While the figures are of little use in assessing the potential impact of livestock contamination to the fishery, they do give an idea of the total numbers of livestock over the broader area. The livestock numbers indicate that sheep, cattle and poultry are present in low numbers (in relation to parish size) in both parishes. The numbers of pigs and horses and ponies were not reported for the Eddrachilles parish due to the small number of holdings.

No livestock, farms or agricultural buildings were observed along the survey route during the site visit undertaken on the 9th July 2013. The OS 1:25000 map identified two sheep pens; one south of the mouth of Unapool Burn and another east of Maldie Burn. The map also shows cattle grids around Kylesku. The presence of these features suggests that livestock have been kept in the area historically, even though there was no evidence of current livestock keeping. However, the shellfish sampling officer for the area commented that she had often seen sheep around the area and that there were also pigs kept at the lochside at Unapool.

Overall, agricultural-source faecal contamination to the fishery is likely to be low.

Figure 5.1 Agricultural parish boundaries

6. Wildlife

Pinnipeds

In a report by the NERC Special Committee on Seals (SCOS), the area between Cape Wrath and Adnamurchan Point (west coast of Scotland) 4,696 common seals were spotted during 2007 and 2008 aerial surveys (Special Committee on Seals, 2012). Loch Glencoul was noted as having one colony of common seals, which was comprised of between 51 and 200 adults.

Both grey and common seals are regularly seen on the shores surrounding Loch Glencoul (Newton Lodge, 2013). Common seals are the most regularly spotted seal, due to their breeding colony within the area, with their population significantly increasing during the pupping season of May to July. Popular haul out sites for both species are on the off-shore islands around Kylesku Bridge and to the southwest on the rocks close to Newton.

During the shoreline survey, one common seal was observed to the west of Loch Glencoul, adjacent to Kylesku. It is likely that both grey and common seals will contribute to background levels of contamination in the loch due to their noted abundance in the area. Contamination levels are expected to be highest during the common seal pupping season (May-July).

Cetaceans

Due to the straits at Caolas Cumhann, it is unlikely that large cetaceans such as whales would enter into Loch Glencoul and Loch Glendhu. No records of sightings of smaller cetaceans (such as porpoises and dolphins) were found during an internet search.

Birds

There are no known RSPB sites or breeding colonies in the area surrounding Loch Glencoul and Loch Glendhu. During the shoreline survey, only 14 arctic terns, and two cormorants were observed. Twelve of these arctic terns were noted flying close to the mussel lines, with the two cormorants noted on the floats of the mussel farm. The harvester also noted that predation from Eider ducks was a problem on the mussel farm. However, no Eider ducks were observed during the survey.

Deer

Both Red and Roe Deer are known to inhabit land around Loch Glencoul. Deer are most likely to be found on the southern shoreline – where there are large hills/mountains (Newton Lodge, 2013).

Otters

The Eurasian Otter (*Lutra lutra*) is common along the coast in the northwest highlands (Scottish National Heritage, 2013). Otters are regularly seen basking on weed covered rocks at low tide around Loch Glencoul (Newton Lodge, 2013). No otters were observed during the shoreline survey, although an ecologist was beginning an otter survey in the area on the day of the survey.

Overall

Species potentially impacting on Loch Glencoul include seals, seabirds, deer and otters. The impact from seals is expected to be greatest during the pupping season (May-July) and is expected to last until pups have been weaned after 3-4 weeks. Contamination levels are expected to be highest at the haul out site at Kylesku, which is <1 km of the western extent of the mussel farm. Birds are also expected to use the mussel farm either to feed on the mussels or to rest on the floats and lines. Impacts from otters and deer are largely unpredictable due to the lack of available data on populations/abundance in the Loch Glencoul/Loch Glendhu area.

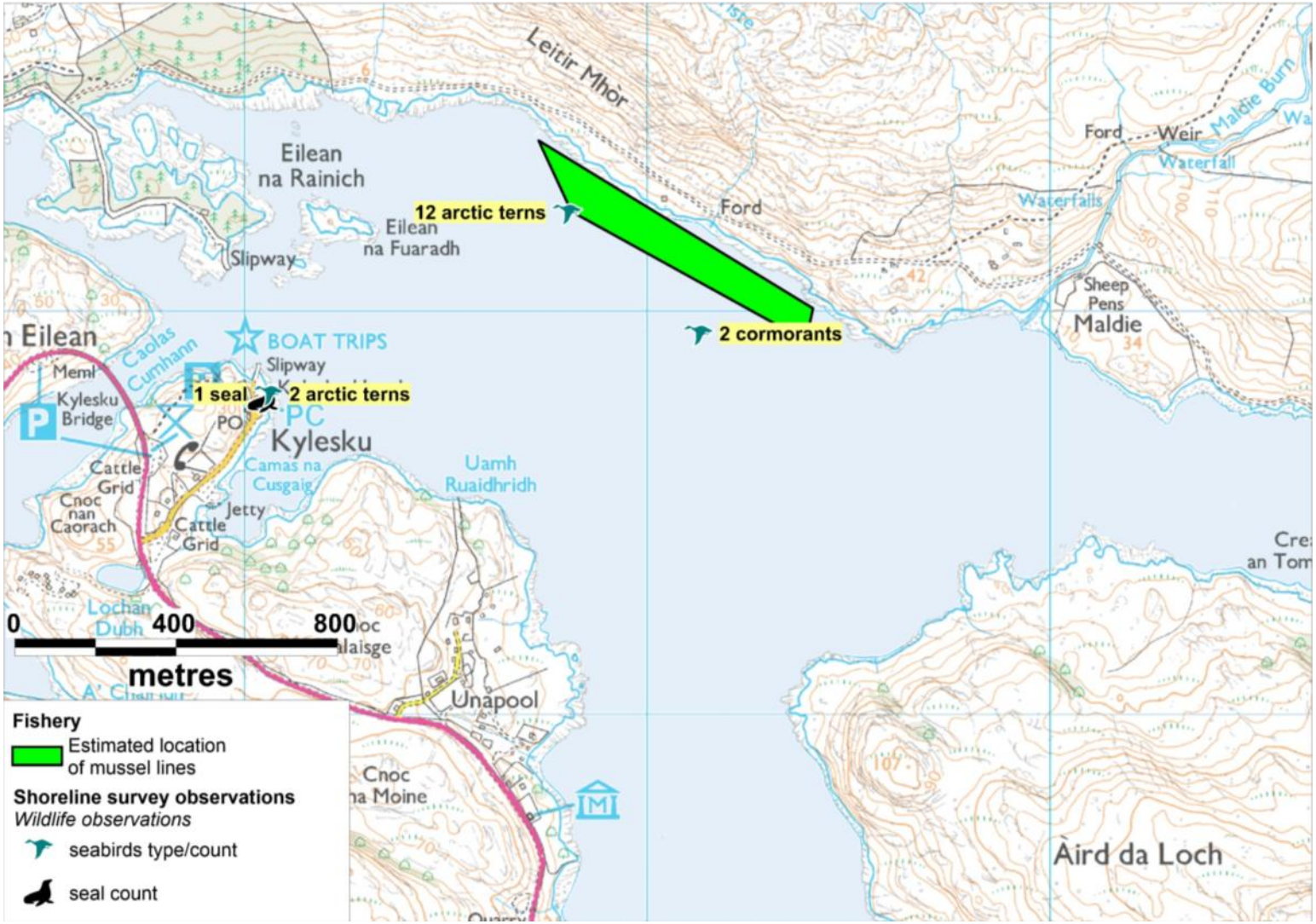


Figure 6.1 Map of shoreline survey wildlife observations at Loch Glencoul

7. Land Cover

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

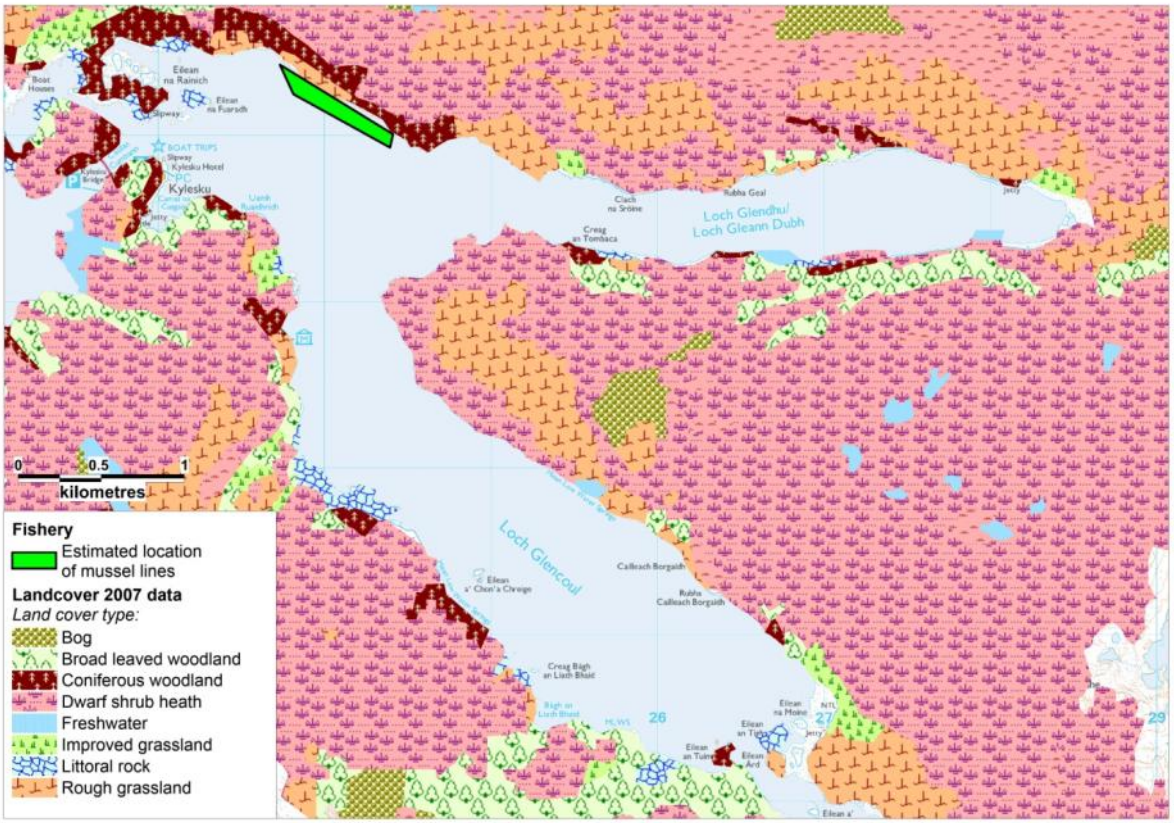


Figure 7.1 LCM2007 land cover data for Loch Glencoul

Dwarf shrub heath is the predominant land cover in the locale with additional areas of rough grassland, broad leaved woodland and coniferous woodland. There are small areas of improved grassland on the shoreline south and west of the fishery and also scattered along the Loch Glencoul shoreline.

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

The highest potential contribution of contaminated run-off to the water bodies are the small areas of improved grassland. However, due to the small size of these and the distance from the mussel farm, the impact at the farm of any runoff from these sources would be low. Contamination from the land cover adjacent to the mussel farm would be generally low but would be expected to increase after rainfall.

8. Watercourses

There are no river gauging stations on watercourses entering Loch Glencoul. A new hydroelectric facility is now in operation that abstracts water directly from Loch an Leathiad Bhuain, with water released from the intake weir into Maldie Burn just before the burn enters Loch Glencoul (Ash Design Assessment, 2009). This scheme is not stated to alter the flow of Maldie Burn overall, though a storage reservoir with a compensation flow outlet to Maldie Burn of 0.3 m^3/s that can run for 30 days is recommended to offset potential changes. However, the report also indicated that this flow would be significantly reduced during dry conditions. The publicly available non-technical summary does not give any information on overall flows in the burn itself. However, a request for further information has been lodged with the hydroelectric company and any updates received will be incorporated into the final report.

The shoreline survey was conducted on the 9th July 2013. Some light showers fell on the day of the survey, but no rainfall was recorded in the week prior to it. Eight watercourses were noted, two flowed under the road and could not be measured or sampled, while a third watercourse could not be sampled due to the steepness of the shoreline. The watercourses noted in Table 8.1 represent the largest freshwater inputs to the Loch Glencoul area.

Table 8.1 Watercourse loadings for Loch Glencoul

No.	NGR	Description	Width (m)	Depth (m)	Flow (m^3/d)	Loading (*E. coli* / day)
1	NC 2380 3184	Unapool Burn	3.00	0.28	54500	$5.5x10^9$
2	NC 2368 3322	Unnamed Watercourse	0.25	0.01	0.400	$6.9x10^8$
3	NC 2274 3460	Unnamed watercourse running under road	Not measured or sampled			Not Determined
4	NC 2309 3459	Unnamed watercourse	0.20	1.50	0.900	Not Determined
5	NC 2332 3457	Unnamed watercourse running under road to shore	1.00	0.03	1.300	$1.3x10^5$
6	NC 2417 3424	Allt Bristle	2.00	0.50	1.700	$1.2x10^7$
7	NC 2478 3412	Fast running watercourse coming from 2 pipes set into hillside, flowing down under the road down to the shore	Not measured or sampled			Not Determined
8	NC 2498 3401	Maldie Burn (waterfall)*	5.00	0.30	64800	$6.5x10^9$

*waterfall flow measurement is likely to reflect an under-representation of the true flow of this watercourse.

Six of the observed watercourses enter the north shore of Loch Glendhu. These all enter the loch within 1 km of the mussel farm, with Allt Bristle discharging directly adjacent to the mussel farm. Two additional watercourses were observed on the western shore of Loch Glencoul.

Loadings estimated from the shoreline survey measurements were low to moderate (between $1.3x10^5$ and $6.5x10^9$ *E. coli* per day) with the highest loading from Maldie

Burn which is located approximately 500 m to the east of the mussel farm. The loading calculated for Maldie Burn is highly uncertain, as the method used to estimate the flow did not capture the full flow of the burn. The loading at Maldie Burn may therefore be higher than that given in Table 8.1.

Overall

Freshwater sources entering Loch Glendhu are expected to have a moderate impact on the the microbiological quality at the mussel farm, primarily arising from the three watercourses that enter the loch within 500 m from the fishery. The loadings would be expected to be higher after rainfall than those estimated from the measurements made during the shoreline survey.

Figure 8.1 Map of river/stream loadings at Loch Glencoul

9. Meteorological Data

The nearest weather station for which a near complete rainfall data set was available is located at Achfary, situated approximately 32 km to the north north west of the production area. Rainfall data was available for January 2007 – December 2012. The nearest wind station is situated in Stornoway Airport, located 80 km west of the fishery. Conditions may differ between this station and the fishery due to the distances between them. However, this data is still shown as it can be useful in identifying seasonal variation in wind patterns.

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

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 *.

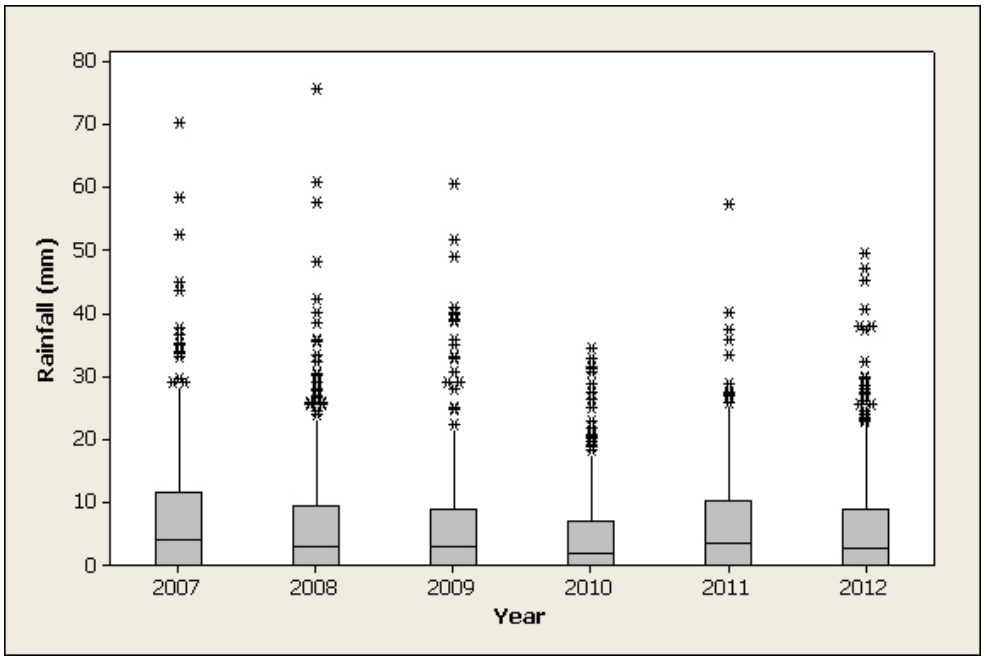


Figure 9.1 Box plot of daily rainfall values by year at Achfary (2007 – 2012)

Daily rainfall values varied from year to year, with 2010 being the driest year so far. The wettest year was 2007. High rainfall values of more than 30 mm/d occurred in all years but an extreme rainfall event of nearly 80 mm/d was seen in 2008.

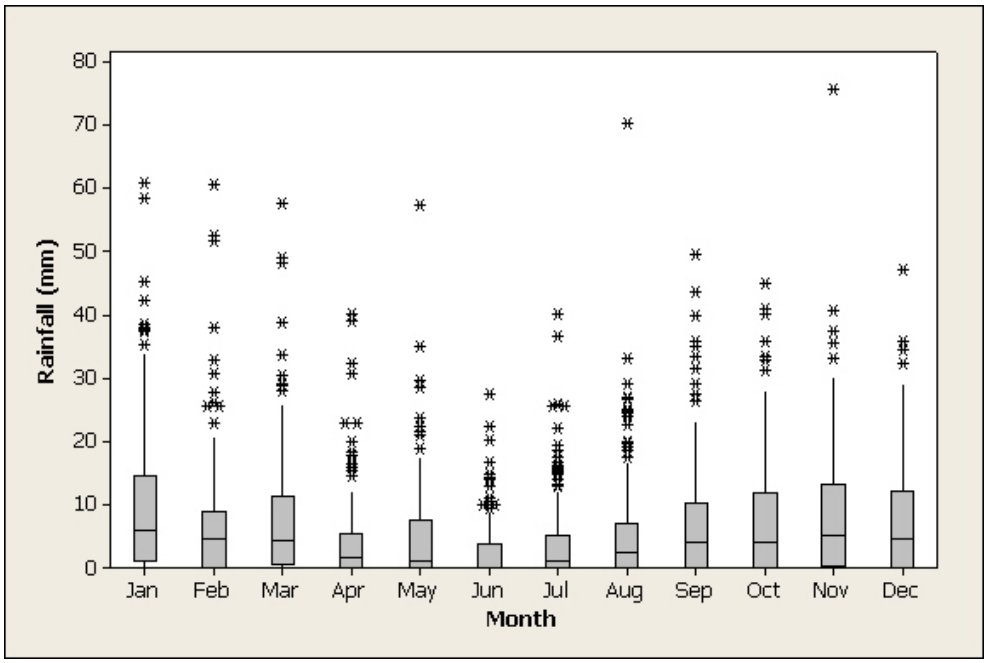


Figure 9.2 Box plot of daily rainfall values by month at Achfary (2007 – 2012)

Daily rainfall values were higher during the autumn and winter. Rainfall increased from August onward and was highest in January and November. Weather was drier from April to July. Rainfall values exceeding 30 mm/d were seen in all months except June. The 2008 extreme event occurred in 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.

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

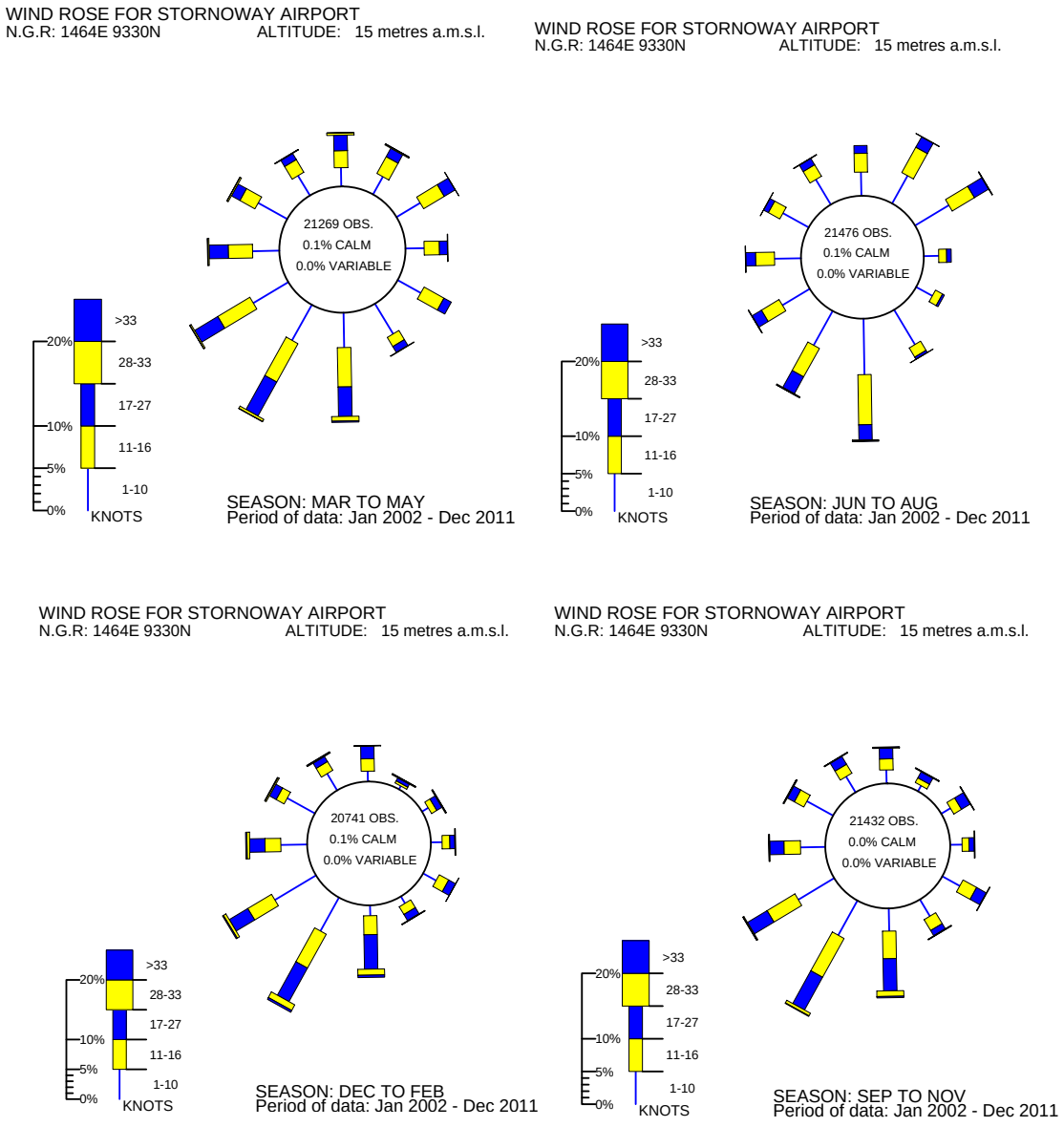


Figure 9.3 Seasonal wind roses for Stornoway Airport

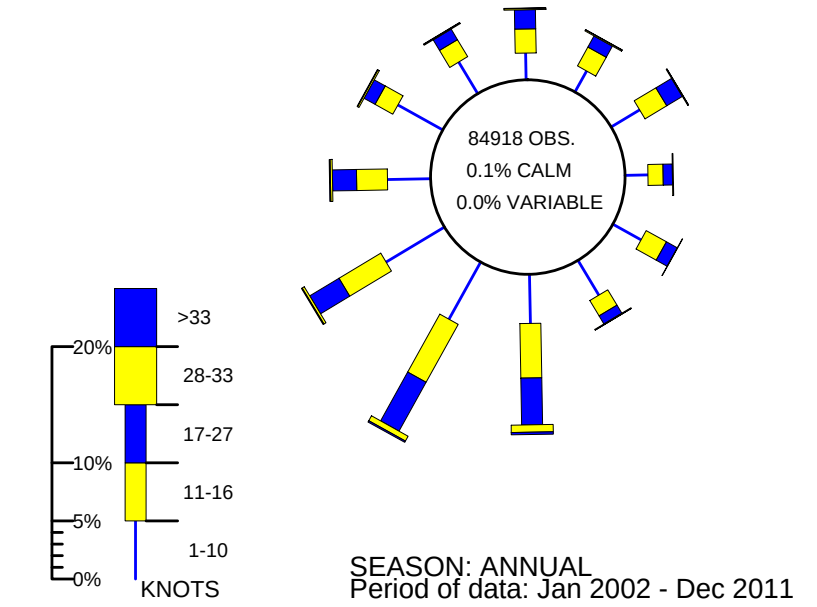


Figure 9.4 Annual wind rose for Stornoway Airport

Overall, winds were predominantly from the southwest. However, during summer, southerly winds predominated and there were also relatively strong winds from the north-west. 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 fishery area.

10. Classification Information

Loch Glencoul has been classified for production of common mussels since 2000. The classification history since 2006 is listed in table 10.1.

Table 10.1 Loch Glencoul classification history

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

The area has typically held A classification year round. There have been instances historically, when the late summer/autumn months have been given B classification.

11. Historical *E. coli* Data

11.1 Validation of historical data

Results for common mussel samples assigned against the Loch Glencoul production area for the period between 01/01/2008 to the 26/07/2013 were extracted from the FSAS database in July 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.

Two common mussel samples were recorded in the database as rejected and were excluded from further analysis. Two reported sampling locations lay significantly north of the Loch Glencoul production area, by 5 km and 15 km respectively. A third lay 1 km southwest of the mussel farm. All three were excluded from the ananlyses. One sample had an incorrect NGR prefix grid letter of NL, but matching grid numbers to other samples. These letters were replaced with the correct prefix of ‘NC’. All samples arrived within the allowed 48 hr window between sample collection and delivery, with all samples having a box temperature of <8°C. Twenty-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

Sampling Summary	
Production area	Loch Glencoul
Site	Kylesku
Species	Common mussels
SIN	HS-157-310-08
Location	Various
Total no of samples	58
No. 2008	10
No. 2009	11
No. 2010	8
No. 2011	11
No. 2012	11
No. 2013	7
Results Summary	
Minimum	<20
Maximum	3500
Median	20
Geometric mean	33
90 percentile	490
95 percentile	988
No. exceeding 230/100g	8 (14%)
No. exceeding 1000/100g	2 (3.4%)
No. exceeding 4600/100g	0 (0%)
No. exceeding 18000/100g	0 (0%)

Sampling at Loch Glencoul has been relatively even across the sampling period 2008-2013. The majority of results have been low, with the median 20 *E. coli* MPN/ 100 g.

11.3 Overall geographical pattern of results

Sampling locations of results are shown in Figure 11.1. One sample was identified as unverified but an NGR was recorded: this was included in Figure 11.1 Two other samples were identified as unverified but no NGRs were given and so the results have not been included in the geographical analysis.

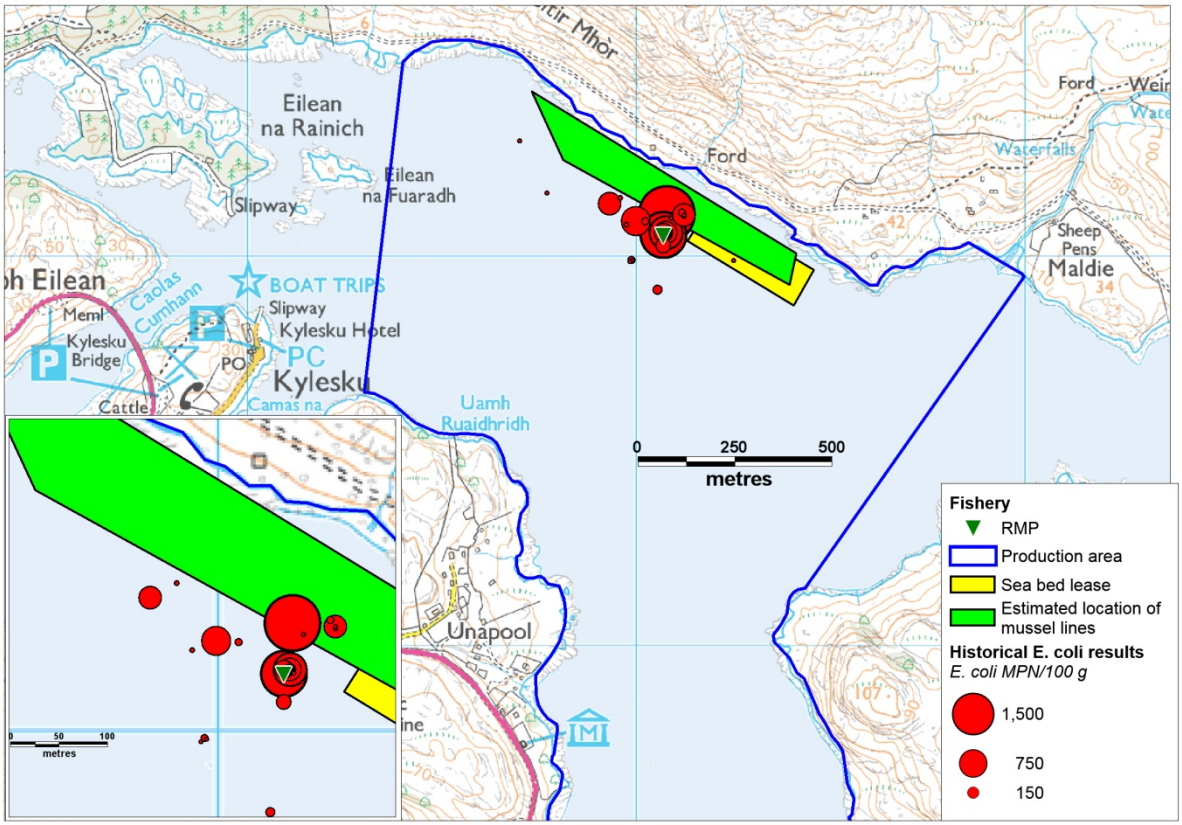


Figure 11.1 Map of Loch Glencoul common mussel sampling result locations

The majority of samples were recorded as having been taken within 100 m of the RMP (NC 2407 3406), which lies 50 m outside of the current boundaries of the mussel lines as provided by the harvester. The highest result of 3500 *E. coli* MPN/ 100 g was taken from within the estimated location of the mussel lines, approximately 60 m north of the RMP.

11.4 Overall temporal pattern of results

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

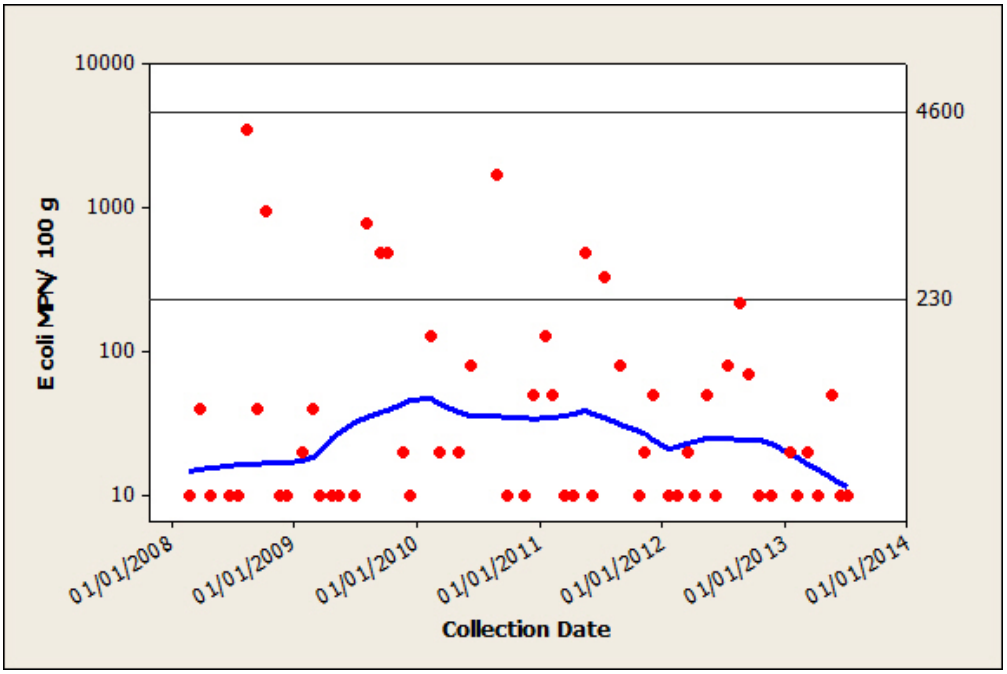


Figure 11.2 Scatterplot of common mussel *E. coli* results by date with a lowess line

The trend line does not show a marked change over the period of sampling and does not indicate any regular changes such as seasonal effects. There has been a decrease in the magnitude of results over time with the highest result being returned by a sample taken in 2008.

11.5 Seasonal pattern of results

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns in human distribution. All of these can affect levels of microbial contamination, causing seasonal patterns in results. A scatterplot of common mussel *E. coli* results by month, overlaid with a lowess line are presented in Figure 11.3. Jittering was applied at 0.02 (x-axis) and 0.001 (y-axis) to ensure that otherwise overlapping points displayed separately.

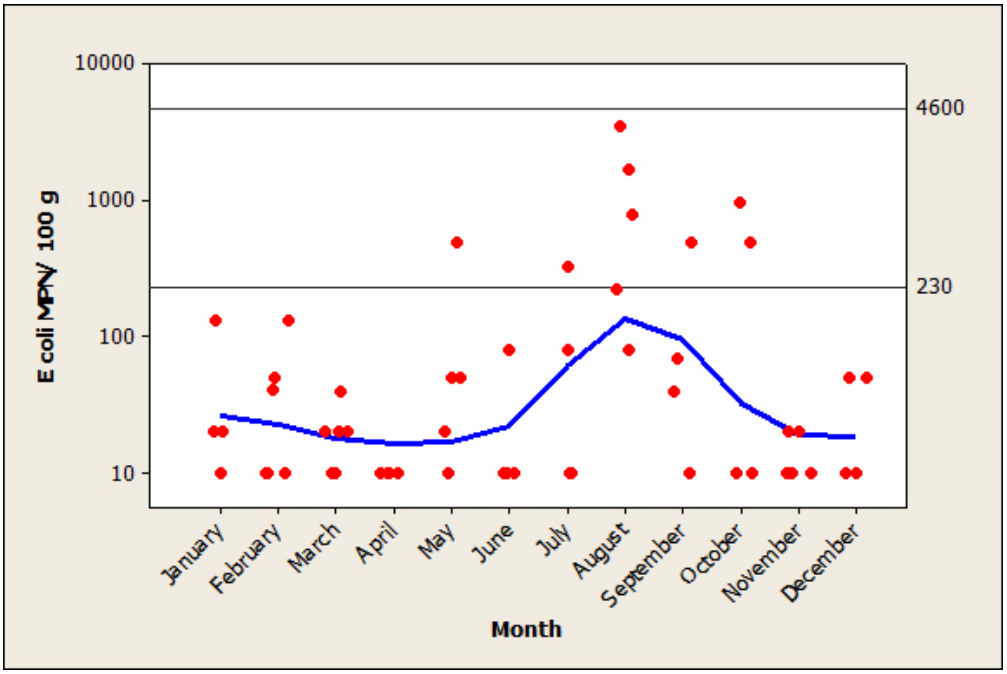


Figure 11.3 Scatterplot of common mussel *E. coli* results by month, fitted with a lowess line

The trend line shows a marked increase between the months of June to August, before gradually decreasing. Results >230 *E. coli* MPN/ 100 g were yielded by samples taken between May and October. Results <20 *E. coli* MPN/ 100 g were reported in every month except for August. Sampling was relatively even across months with between 4 and 6 samples taken for all months. For statistical evaluation, seasons were split into spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). A boxplot of common mussel *E. coli* results by season is presented in Figure 11.4.

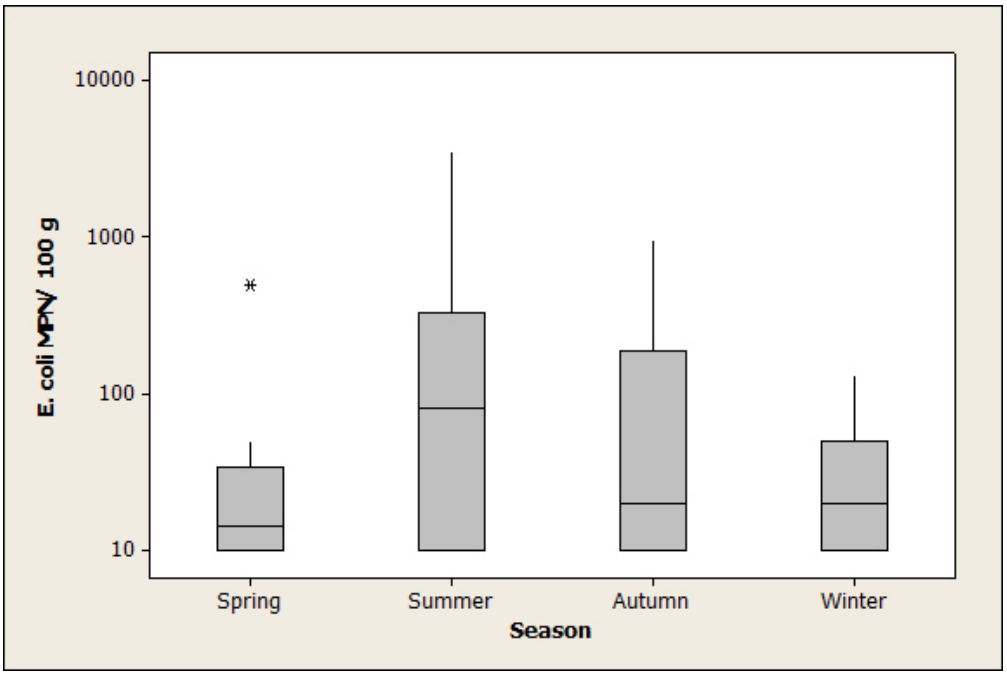


Figure 11.4 Boxplot of common mussel *E. coli* results by season

No statistically significant difference was found between common mussels results by season (one-way ANOVA, F = 1.75, p = 0.168, Appendix 4).

11.6 Analysis of results against environmental factors

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

11.6.1 Analysis of results by recent rainfall

The nearest weather station with available rainfall data was at Achfary, approximately 9 km 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

A scatterplot of mussel *E. coli* results against total rainfall recorded on the two days prior to sampling is presented in Figure 11.5. Rainfall was recorded 49/58 common mussel samples. Jittering was applied to results at 0.025 (x-axis) and 0.001 (y-axis) respectively.

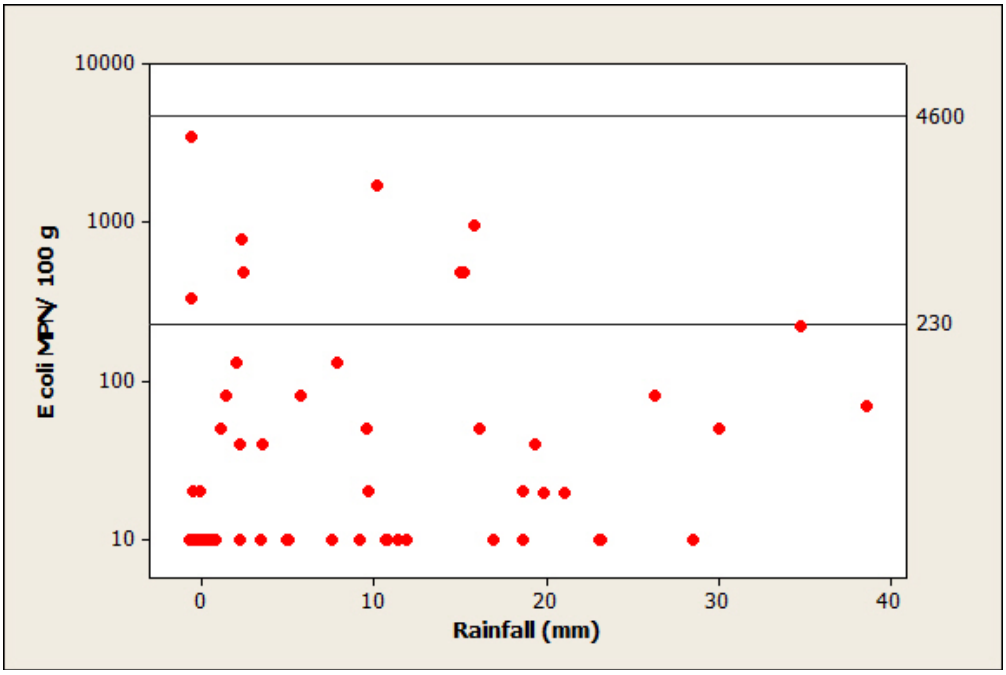


Figure 11.5 Scatterplot of common mussel *E. coli* results against rainfall in the previous two days

No significant correlation was found between mussel *E. coli* results and 2-day rainfall (Spearman's rank correlation r = 0.069, p = 0.639. However, high results tended to be associated with low (or zero) to moderate levels of rainfall.

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. A scatterplot of mussel *E. coli* results against total rainfall recorded for the seven days prior to sampling is presented in Figure 11.6. Jittering was applied to results at 0.025 (x-axis) and 0.001 (y-axis) respectively.

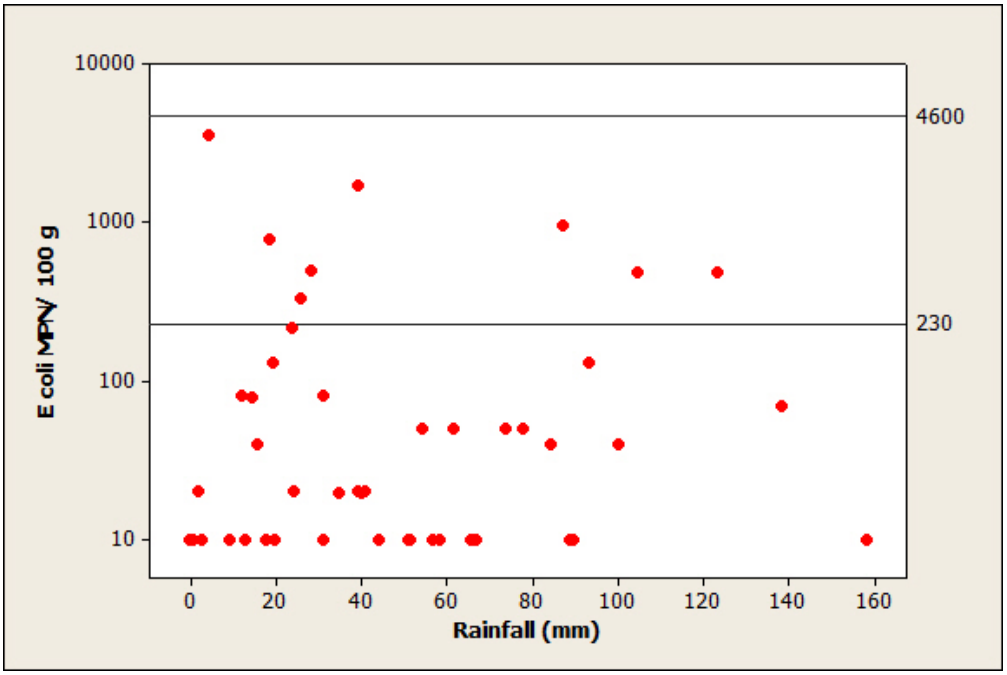


Figure 11.6 Scatterplot of common mussel *E. coli* results against rainfall in the previous seven days

No significant correlation was found between mussel *E. coli* results and 7-day rainfall. (Spearman's rank correlation r = 0.054, p = 0.211).

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. A polar plot of common mussel *E. coli* results against the lunar cycle is presented in Figure 11.7. 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.

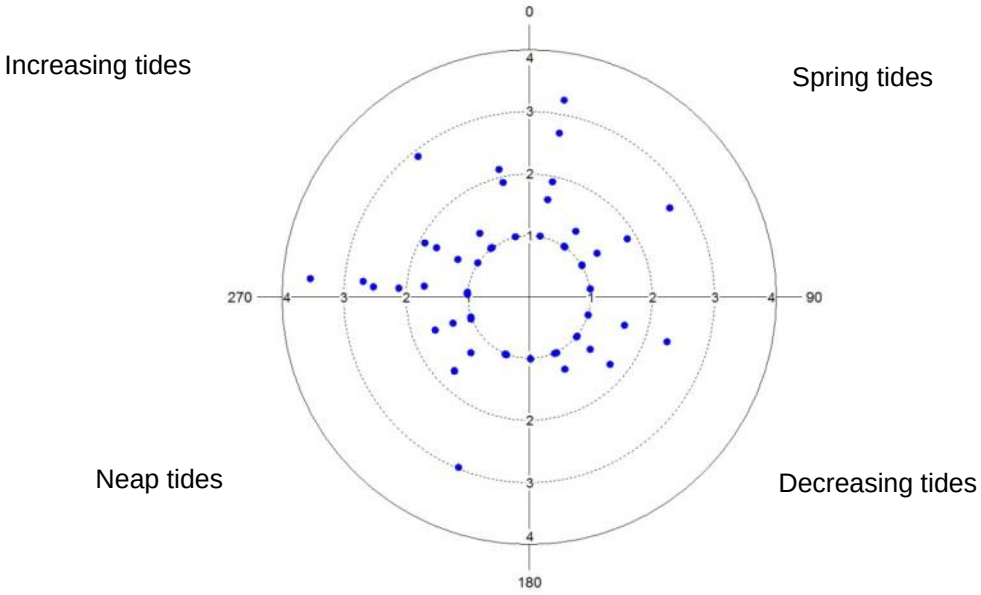


Figure 11.7 Polar plot of mussel log_{10} *E. coli* results against the spring/neap tidal cycle

A statistically significant correlation was found between mussel log_{10} *E. coli* results and the spring/neap tidal cycle (circular-linear correlation r = 0.259, p = 0.025). The majority of high results were taken during increasing tides

High/Low Tidal Cycle

Predicted high and low water times at Ullapool were extracted from POLTIPS-3 in July 2013. This site was the closest to the production area and it is assumed that tidal state will be very similar between sites.

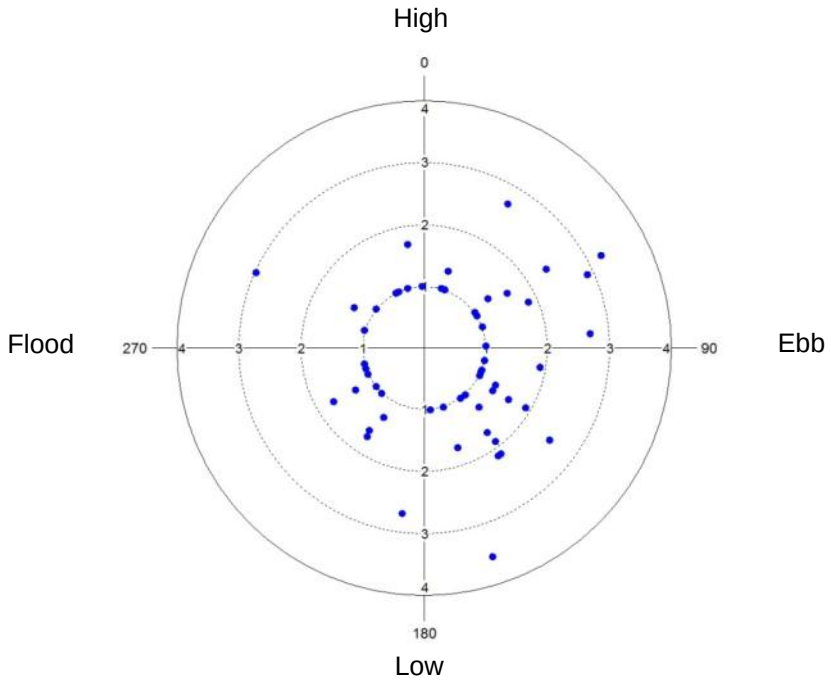


Figure 11.8 Polar plot of mussel log$_{10}$ *E. coli* results against the high/low tidal cycle

A statistically significant correlation was found between common mussel log$_{10}$ *E. coli* results and the high/low tidal cycle (circular-linear correlation r = 0.239, p = 0.043). The majority of the high results occurred on an ebb tide.

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. A scatterplot of common mussel *E. coli* results against water temperature is presented in Figure 11.9. Thirty-one out of the 58 common mussel results had water temperature data associated with them. Jittering was applied at 0.01 (x-axis) and 0.001 (y-axis) respectively.

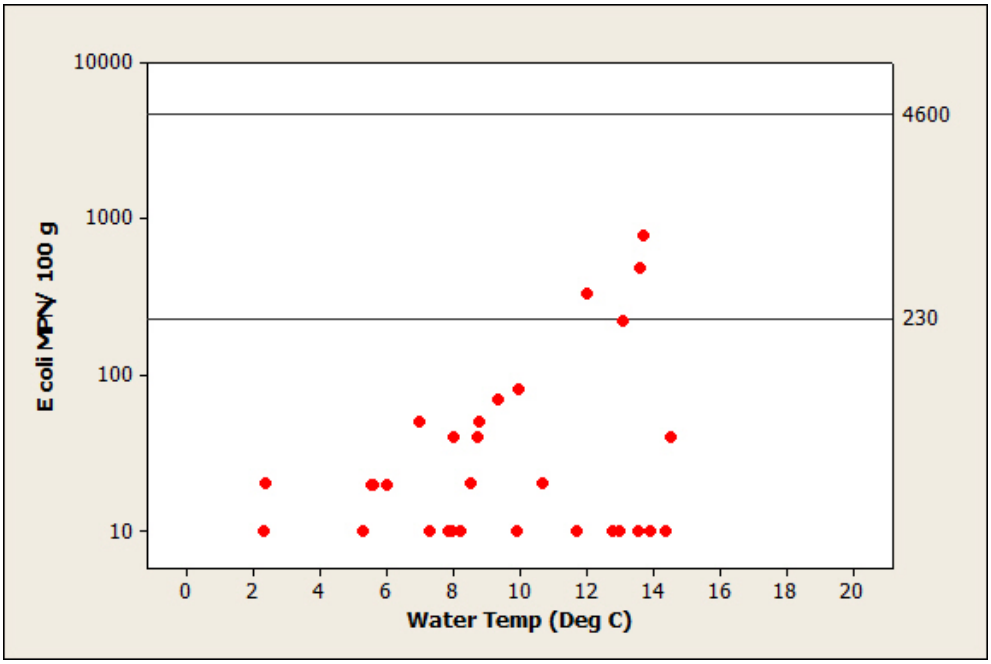


Figure 11.9 Scatterplot of common mussel *E. coli* results and water temperature

No statistically significant correlation was found between common mussels *E. coli* results and water temperature (Spearman's rank correlation r = 0.185, p = 0.320).

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. A scatterplot of common mussel *E. coli* results against water salinity is presented in Figure 11.10. Salinity measurements were taken for 33/58 common mussels samples. Jittering was applied to results at 0.01 (x-axis) and 0.001 (y-axis) respectively.

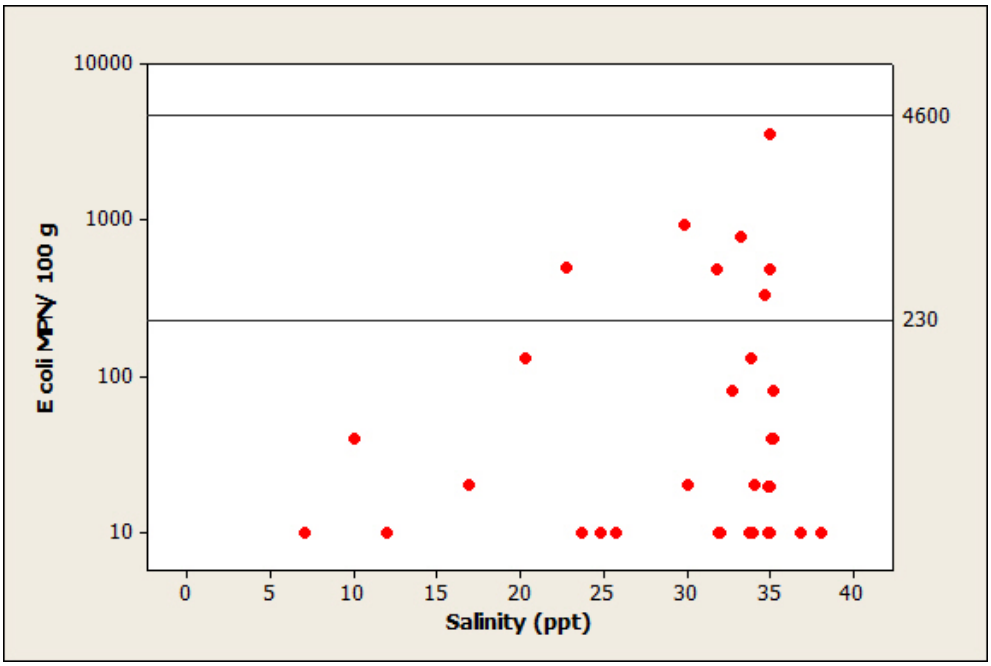


Figure 11.10 Scatterplot of common mussel *E. coli* results and salinity

No statistically significant correlation was found between common mussels *E. coli* results and water salinity (Spearman's rank correlation r = 0.046, p = 0.798). The majority of results were taken at salinities from 30-35 ppt.

11.7 Evaluation of results over 1000 *E. coli* MPN/ 100 g

Mussel results exceeding 1000 *E. coli* MPN/ 100 g for Loch Glencoul are listed in Table 11.2.

Table 11.2 Loch Glencoul historical *E. coli* results >1000 *E. coli* MPN/100 g

Collection Date	*E. coli* (MPN/100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (^{o}C)	Salinity (ppt)	Tidal state (high/low)	Tidal State (spring/neap)
12/08/2008	3500	NC 2408 3411	0.00	8.10	-	35	Ebb	Increasing
24/08/2010	1700	NC 2407 3406	10.50	37.40	-	-	High	Spring

-No data available

No results exceeding 1000 *E. coli* MPN/ 100 g have been obtained since 2010.

Both high results were from samples taken during August. Rainfall on the two and seven days prior to sampling varied between the two samples, with one being associated with low levels of rainfall and the other with moderate levels.

11.8 Summary and conclusions

Sampling at Loch Glencoul has generally been consistent over the sampling period, with between eight and eleven samples taken all years. Location of these samples has been generally consistent, with most taken within 50 m of the RMP. However these samples predominantly sit outside the current location of the mussel farm provided by the harvester. Sampling results have varied between <20 and 3500 *E. coli* MPN/ 100 g, though the majority of results have been low with the median at 20 *E. coli* MPN / 100 g.

Results >230 *E. coli* MPN/100 have occurred between May and October. There were significant correlations between the magnitude of *E. coli* results and both the spring/neap and high/low tidal cycles with higher results generally being seen on increasing (with respect to spring/neap cycle) and ebb tides (with respect to high/low cycle).

12. Designated Shellfish Growing Waters Data

The Loch Glencoul production area encompasses the Loch Glendhu designated Shellfish Growing Water (SGW) as shown in Figure 12.1 (SEPA, 2011). The SGW was originally designated in 2002 and under the current legislation must be monitored quarterly for faecal coliforms in the shellfish flesh and intervalvular fluid. SEPA is responsible for ensuring that this monitoring is undertaken.

The relative positions of the production area, RMP, Shellfish Growing Waters (SGW) boundary and the previous SGW monitoring point are shown in Figure 12.1. Since 2007, SEPA have based the SGW assessment on FSAS *E. coli* results. The *E. coli* results have been reviewed in Section 11 of this report.

The shellfish growing water report for the area identified the land bordering Loch Glencoul is predominantly semi-natural grassland, heather moorland and rough or rocky ground. The area does not have any settlements of significant size. The only freshwater input to the designated area is Allt Briste and is considered to be of at least good quality. The 2011 SGW report identified that the area complied with the Guideline standard for faecal coliforms from 2003 to 2010 (the last year given in the report).

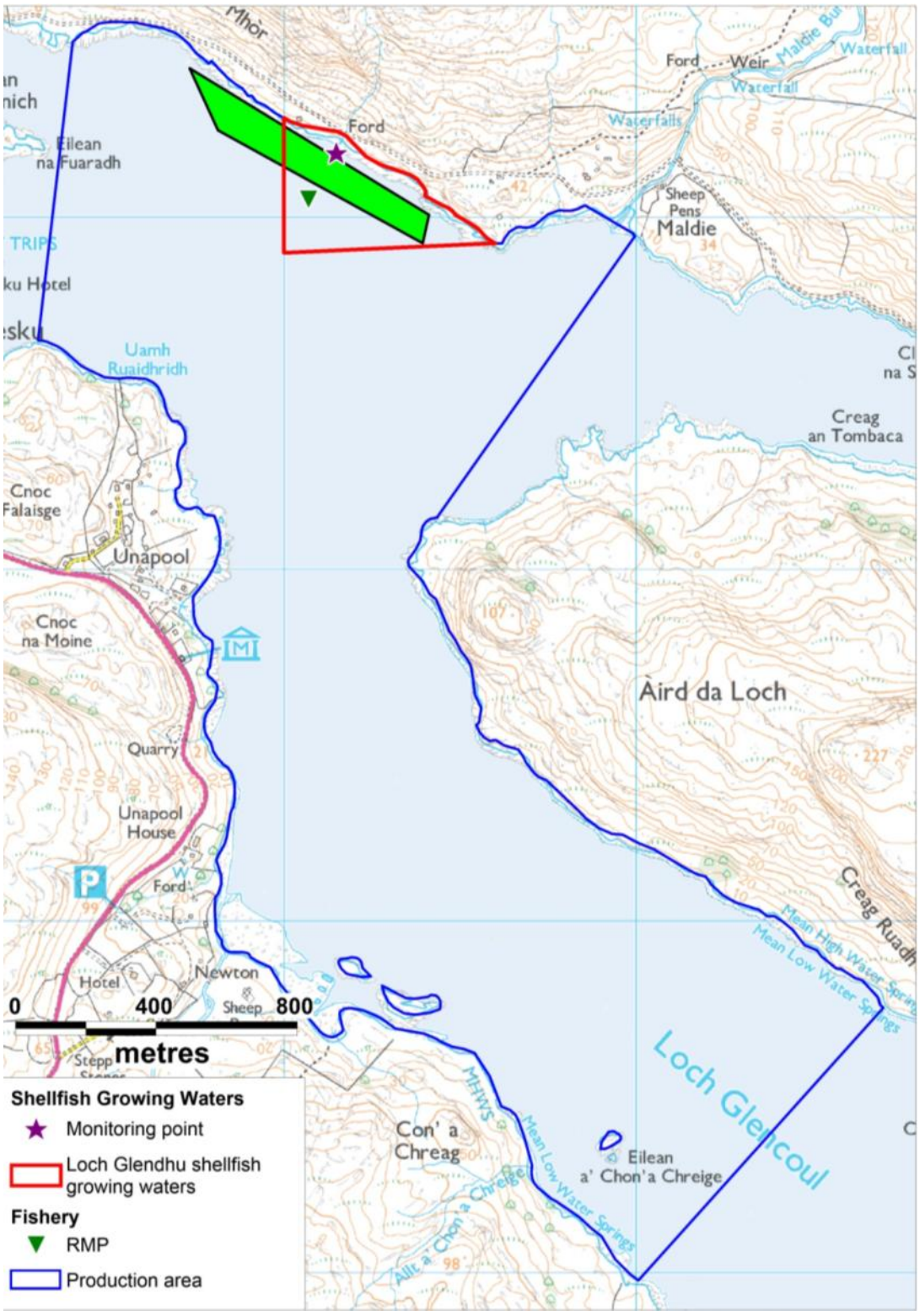


Figure 12.1 Designated shellfish growing water – Loch Glendhu

13. Bathymetry and Hydrodynamics

13.1 Introduction

13.1.1 The Study Area

The study area comprises a system of sea lochs situated to the extreme northwest of Scotland in Sutherland approximately 60 km south of Cape Wrath and 40 km NNE of Ullapool. The area of assessment is the inner part of Chàirn Bhàin which links through a narrow channel to a 'Y'-shaped loch system of Loch Glencoul and Loch Glendhu; this is collectively called Cairnbawn (Edwards & Sharples, 1986). Loch a' Chàirn Bhàin connects the system to the coast and extends east from Eddrachillis Bay for approximately 6.5 km where it then splits at the narrows at Caolas Cumhann. The northerly branch forms the narrow Loch Glendhu which is around 4.5 km long and the southerly branch forms Loch Glencoul which is around 5 km long making the whole system roughly 15 - 16 km in length. The physical set-up of the loch complex means that the assessment area is relatively sheltered from conditions at the open sea boundary. The narrows contain the peninsular of Garbh and Kylesku and also the rocky outcrops of Eilean na Rainich and Eilean ne Fuaradh.

Coordinates where Loch Glencoul and Loch Glendhu merge :

58° 15.5' N 005° 0.00' W

NC 240 335

Figure 13.1 Extent of hydrographic study area

13.2 Bathymetry and Hydrodynamics

13.2.1 Bathymetry

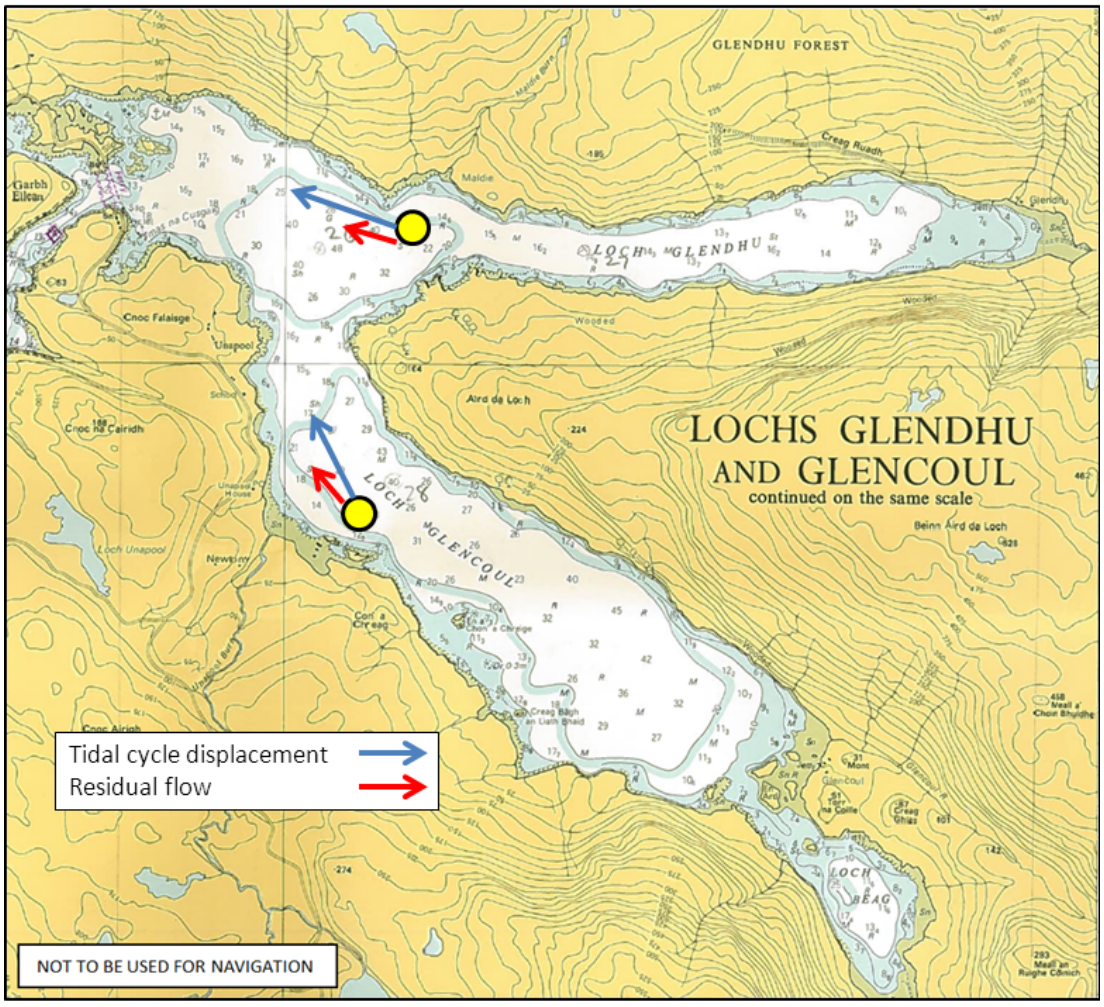


Figure 13.2 Admiralty chart extract (2502) for Loch Glencoul.
Note that the length of the flow arrows at the current meter sites approximately equate with the estimated transport distance during the flood or ebb phases of the tide.

Within the system of lochs (Cairnbawn), the maximum charted depth is 93 m at the eastern end of Loch a' Chàirn Bhàin before the system of islands and outcrops. Cairnbawn covers an area of around 15 km x ~1 km with an estimated mean low water depth of 28.3 m. The estimated low water volume is 4.4 x 10^8 m^3 (Edwards & Sharples, 1986). Figure 2.1 shows bathymetry of Loch Glencoul and Loch Glendhu. There are 3 sills in the assessment area (Edwards & Sharples, 1986), one at the narrows, one at the mouth of Loch Glencoul and the other at the head where it links to Loch Beag.

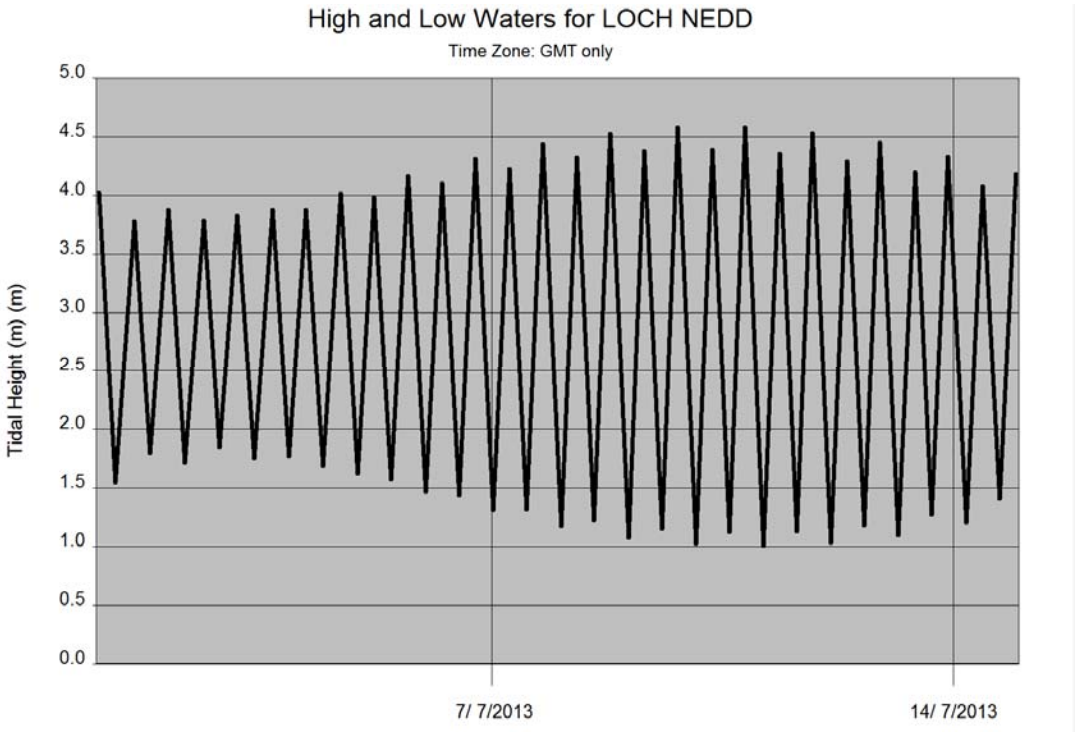
Over much of Loch Glencoul depths are typically greater than 20 m with a maximum charted depth of 45 m near the northeast shore towards the head of the loch. In

comparison, Loch Glendhu has depths typically less than 20 m with a maximum charted depth within the body of the loch of just 16 m. At their junction, near Kylesku there is a deeper basin with depths approaching 50 m. In Loch Glencoul the shoreline is typically steep from shore towards the inner reaches of the loch especially on the north side with depths increasing to > 20 m within about 100 – 150 m of the shore. At the head of the loch and on the southern shore there are rocky intertidal areas. In Loch Glendhu the gradients at the shore line are generally less steep, with depths increasing to only 10 m over a similar 100-150m distance, but it is relatively uniform around the perimeter of the loch. There is a small intertidal area at the head of Loch Glendhu.

13.2.2 Tides

Lochs Glencoul and Glendhu are expected to have a typical semi-diurnal tidal characteristic. Data on tidal height information is given from charted information. The nearest location for tidal predictions is Loch Nedd situated approximately 4 km southwest from the mouth of Loch a' Chàirn Bhàin [http://easytide.ukho.gov.uk]. However, it is likely that the narrows will tend to modify the regular, sinusoidal tidal response in the assessment area.

Standard tidal data for Loch Nedd are given below (from Admiralty Surveys) and the spring/neap cycle of tidal height around the time of the survey (week beginning 8th July 2013) is shown in Figure 2.2:



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

Figure 13.3 Two week tidal curve for Loch Nedd.

Tidal Heights:

Mean High Water Springs = 4.9 m
Mean Low Water Springs = 0.7 m
Mean High Water Neaps = 3.7 m
Mean Low Water Neaps = 1.9 m

Tidal Ranges:

Mean Spring Range = 4.2 m
Mean Neap Range = 1.8 m

Assuming similar tidal ranges within Cairnbawn gives a tidal volume of water during each tidal cycle of approximately:

Springs: 6.5×10^7 m^3
Neaps: 2.8×10^7 m^3

13.2.3 Tidal Streams and Currents

Admiralty Chart number 2502 has a tidal diamond at the narrows in the passage called Caolas Cumhann between Loch a' Chàirn Bhàin and the seabed lease, shown within Figure 2.1. The flow is aligned parallel to the coast in the directions of 055°/235°. The flood tide flows generally northeast (NE) and the ebb tide flows southwest (SW). The tidal flow is typically rectilinear (back and forth) rather than elliptical suggesting it is strongly constrained by the coastline. The maximum rates are 2.5 knots (1.3 m/s) at Springs and 1.0 knots (0.5 m/s) at Neaps. These values are only of relevance to that specific location and do not apply to the rest of the Loch system. Therefore, tidal cycle displacement and residuals have not been calculated. It should be remembered that data at tidal diamonds may only be relatively crude indications of flow characteristics derived from short current records (e.g. Bell and Carlin, 1998).

Rather limited information on the circulation in the study area was extracted from published literature. The Cairnbawn system of lochs have a diverse range of exposures to wave action and tidal streams (Barne, et al., 1997). Current speeds and accelerated tidal movements are evident within the narrows (Connor & Little, 1998).

Current data from previous surveys have been assessed. Current data were obtained from SEPA which were collected from Loch Glencoul and Glendhu, locations in Figure 2.1. A quality check of this data determined that there were inconsistencies in the current direction from each current meter and the documentation for the deployments was not complete. However the data do provide a general assessment on the magnitude of the flow and the direction will most likely follow the contour of the Loch. In the documentation provided with the data, surface refers to a depth 2 m below surface, mid-depth is 7 m below surface and bottom is 21 m below surface. The water depth (at low water) of the survey site was reported as 22 m in Loch Glencoul and 26 m in Loch Glendhu. The data summary is given in Tables 2.3.1 and 2.3.2.

Using a surface principal current amplitude of 0.05 m/s (Tables 2.3.1 and 2.3.2) and the assumption of a uniform sinusoidal tide, the cumulative transport that might be expected during each phase of the tide has been estimated as approximately 700 m. No distinction is made here for springs and neaps.

There is no indication in the data of what the magnitude of the residual flow might be but from the location it may be anticipated that there would be a weak residual flow to seaward and the data do show an enhanced surface flow in the mean speed.

Table 13.1 Loch Glencoul current data measured in 1999

	Bottom	Mid-depth	Surface
Mean Speed (ms^{-1})	0.027	0.053	0.073
Principal Axis Amp (ms^{-1})	0.03	0.04	0.05
Residual speed (ms^{-1})		Not reported	
Residual direction (^oM)		Not reported	

Table 13.2 Loch Glendhu current data measured in 1999

	Bottom	Mid-depth	Surface
Mean Speed (ms-1)	0.044	0.048	0.098
Principal Axis Amp (ms-1)	0.03	0.03	0.05
Residual speed (ms-1)		Not reported	
Residual direction (^oM)		Not reported	

Dispersion is an important property of a water body with respect to redistribution of contaminants over time. There are no direct measurements of dispersion in the assessment area or any published data relating to dispersion. Without such data it is difficult to judge how dispersive the site might be, but the relatively fast tidal flow through the narrows, and the presence of small promontories and islets in the vicinity of this flow may enhance dispersion in the western part of the study area. However, it is likely that the dispersion will be much lower towards the head of each loch.

13.2.4 River/Freshwater Inflow

There are a number of watercourses marked on the OS map. Maldie Burn and Allt Briste flow directly into the area around the seabed lease in the northern part of the study area. Unapool Burn enters Loch Glencoul from Newton. Allt a' Chon' a Chreige is to the south of Unapool Burn and enters the middle of Loch Glencoul from the southern shore. Glencoul River flows into the head of the loch. There are also numerous unnamed watercourses entering into the system. It is uncertain which of these will continue to flow in drier weather. The annual precipitation in the general Cairnbawn area is 1750 mm and the annual freshwater runoff is estimated as 260.2 Mm^3yr^{-1} (Edwards & Sharples, 1986). The ratio of fresh water volume to tidal volume across the whole loch complex is low at approximately 1:125 (Edwards & Sharples, 1986), though of course this will have considerable seasonal variability and the fresh water influence will be greater at the head of the two Lochs.

13.2.5 Meteorology

Rainfall data were taken from Achfary which is situated roughly 32 km northeast of the assessment area and spanned the time frame from January 2007 to December 2012.

The year with the highest rainfall was 2007 and the least rain fell in 2012. In 2008, an unusual maximum of 80 mm/d occurred but generally high rainfall values (>30 mm/d) were seen in all years. The highest daily rainfall values occurred throughout the autumn and winter seasons where rainfall increased from August onwards. The highest recorded rainfall was in November and January. Rainfall was lower in the months April to July. There was rainfall of >30 mm/d in all months with the exception of June. For the duration of the data set, daily rainfall of below 1 mm occurred 40% of the time and daily rainfall of above 10 mm occurred 18% of the time.

It can be surmised from these data that run-off due to rainfall is expected to be higher in the autumn and winter months but it must also be noted that high rainfall and consequently high run-off can occur in most months.

Data about wind conditions were collected from Stornoway Airport which is located 80 km west of the production area on the north east coast of the Isle of Lewis. Due to the distance between the two areas, the wind rose statistics may not be directly transferrable to the specific production area in Loch Glencoul but they can be used to give a general picture of the seasonal wind conditions in the northwest area. The data from Stornoway shows that overall westerly winds and southerly winds were stronger than northerly or easterly winds. There is a predominant south-westerly airflow year round for the area. It is highly likely that the wind direction will be strongly influenced in Loch Glencoul and Loch Glendhu by the morphology of the surrounding high ground.

13.2.6 Model Assessment

Due to the complexity of the combined loch system and the sparse data available a model assessment was not undertaken for this location. However, the tidal prism method for assessing exchange in loch environments gives a flushing time of 5 days for Carinbawn(Edwards & Sharples, 1986).

13.3 Hydrographic Assessment

13.3.1 Surface flow

The site and the meteorological data indicate that there is likely to be a rather persistent freshwater discharge into the surface waters of each loch, though the absolute value of discharge is likely to rather small and have a strong seasonal variation. It is expected that this discharge would manifest itself as a weak estuarine flow with surface residual flows to seaward.

Although the current meter records were not sufficient to determine all parameters, it is likely that the principle current direction in the surface water will be aligned with the shore line with a magnitude of ~ 0.05 ms^{-1}. Cumulative transport during each phase of the tide has been estimated to be less than 1 km. Transport in the deeper water is likely to be rather less as the current meter data show slightly smaller current amplitude.

No reliable measurement of the residual flow is available but from similar systems one might expect a weak seaward flow of approximately 0.01 ms^{-1} giving a net residual transport over the tidal cycle of a few hundred meters.

In the narrows, surface currents are greatly enhanced, peaking at 1.3 ms^{-1}. However, this is limited to a relatively confined region of the assessment area. Its impact on exchange and dispersion will probably only be felt within a relatively short distance of the narrows, particularly as there is a deep basin close to the narrows. It can be seen that the impact of flow from the narrows is not felt strongly at the location of the current meter moorings.

Neither of the two lochs in the assessment area are particularly long and the freshwater discharge occurs at numerous locations along their length so there is unlikely to be significant variation in the surface properties along their axes. The relatively minimal freshwater discharge, compared to tidal exchange, would suggest that stratification might dominate only under exceptionally calm conditions. At times of strong wind there would be sufficiently long fetch along the axis of each loch to provide effective vertical mixing.

Loch Glencoul lies perpendicular to the prevailing southwest winds but it is likely that the local shape of the surrounding hills would steer the winds along the axis of the loch enhancing surface flow, dispersion and mixing.

Loch Glendhu lies east west and is likely to experience greater surface wind forcing with surface flow directed up the loch during periods of more frequent westerly winds.

Given the current meter measurements in each Loch, 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

Lochs Glencoul and Glendhu are part of a complex loch system referred to as Cairnbawn. Any exchange for these lochs occurs through a rather narrow passage at Kylesku. This will undoubtedly impact the free exchange of waters. Further the basin

depth at the conjunction of Loch Glencoul and Glendhu is approximately three times the sill depth leading to potential stagnation of the deep waters.

The flushing time for the entire system has been estimated from tidal considerations as 5 days. However it may be anticipated that the exchange for the surface waters would be less than that. Therefore the flushing characteristics of the assessment area can be described as being ‘moderately flushed’ with the flushing rates of the surface being enhanced during times of enhanced run-off and/or along axis wind.

There is a limited amount of available current meter data for this area and there is a paucity of any measured hydrographic data or model output. Therefore the confidence level of this assessment is LOW.

14. Shoreline Survey Overview

The shoreline survey was conducted on the 9th July 2013. No rainfall was recorded for the previous week prior to the survey, with some light rain on the day of the survey. The boundaries of the mussel farm were not recorded during the shoreline survey but were later provided by the harvester.

The fishery at Loch Glencoul is comprised of a common mussel farm, located to the northeast. Mussels are grown on suspended culture lines with droppers to 6-8 m depth. The harvester informed the survey team a newly established spat settlement site comprising of four lines had been erected to the southeast to help with very sporadic spat settlement. This site was not visited during the survey. Harvesting at the site has been stopped temporarily whilst the new hydroelectric facility on Maldie Burn (east) was constructed. All shellfish samples returned results of <20 *E. coli* MPN /100 g and seawater samples were also low at 1 and 0 *E. coli* cfu /100 ml at the southeast and northeast corners of the farm respectively.

The surrounding shoreline was sparsely populated. Small settlements exist at Kylesku (10 private dwellings, one hotel and a public toilet), Unapool (12 dwellings) and to the northwest where estate buildings associated with Reay Forest Estate are situated. A new hydroelectric facility (RWE Npower Renewables Ltd (RNE)) is also located to the northeast. The majority of these houses were noted as being private dwellings, with 10 holiday lodges located at the Reay Forest Estate and one at Kylesku.

No public sewage facilities were found around the loch. One actively flowing sewage pipe was noted to be discharging from the public toilets in Kylesku and the seawater samples taken adjacent to the pipe returned a results of >10,000 *E. coli* cfu/ 100 ml. All other seawater samples returned low results, with one notable elevated result to the southeast at 76 *E. coli* cfu/ 100 ml.

Three piers/slipways were observed, which were mostly used by boats servicing the mussel lines, tourist boats operating tours around the loch and fishing trips.

Most of the immediate land surrounding the loch was steep and mountainous with rocky shoreline bordering the majority of the loch perimeter. Land cover along the northern shoreline was rough grazing, mostly associated with the Reay Forest Estate. On the southwestern side, land was mostly used for plantation forestry with some areas of rough grazing.

Sheep were noted in scattered populations away from the shoreline. In total <30 sheep were observed.

Three large watercourses Unapool Burn (southwest), Allt Bristle and Maldie Burn (North) and two smaller watercourses measuring <1 m wide enter into the loch.

Maldie Burn enters via Eas a' Chuall Aluinn waterfall adjacent to the hydroelectric facility. Three of the five freshwater samples returned low results of <10 or 10 *E. coli* cfu / 100 ml, while two samples yeilded high results of 700 (Allt Bristle) and at 16000 (Unapool Burn) *E. coli* cfu /100 ml.

Twelve Arctic terns were observed flying over the mussel farm, with two cormorants observed on one of the floatation barrels during the survey. The harvester indicated that Eider ducks were responsible for predating on the top of the droppers, with only small mussels present. Two arctic terns and a seal were observed at Kylesku. At the time of the survey an ecologist was conducting a survey of otters in the area.

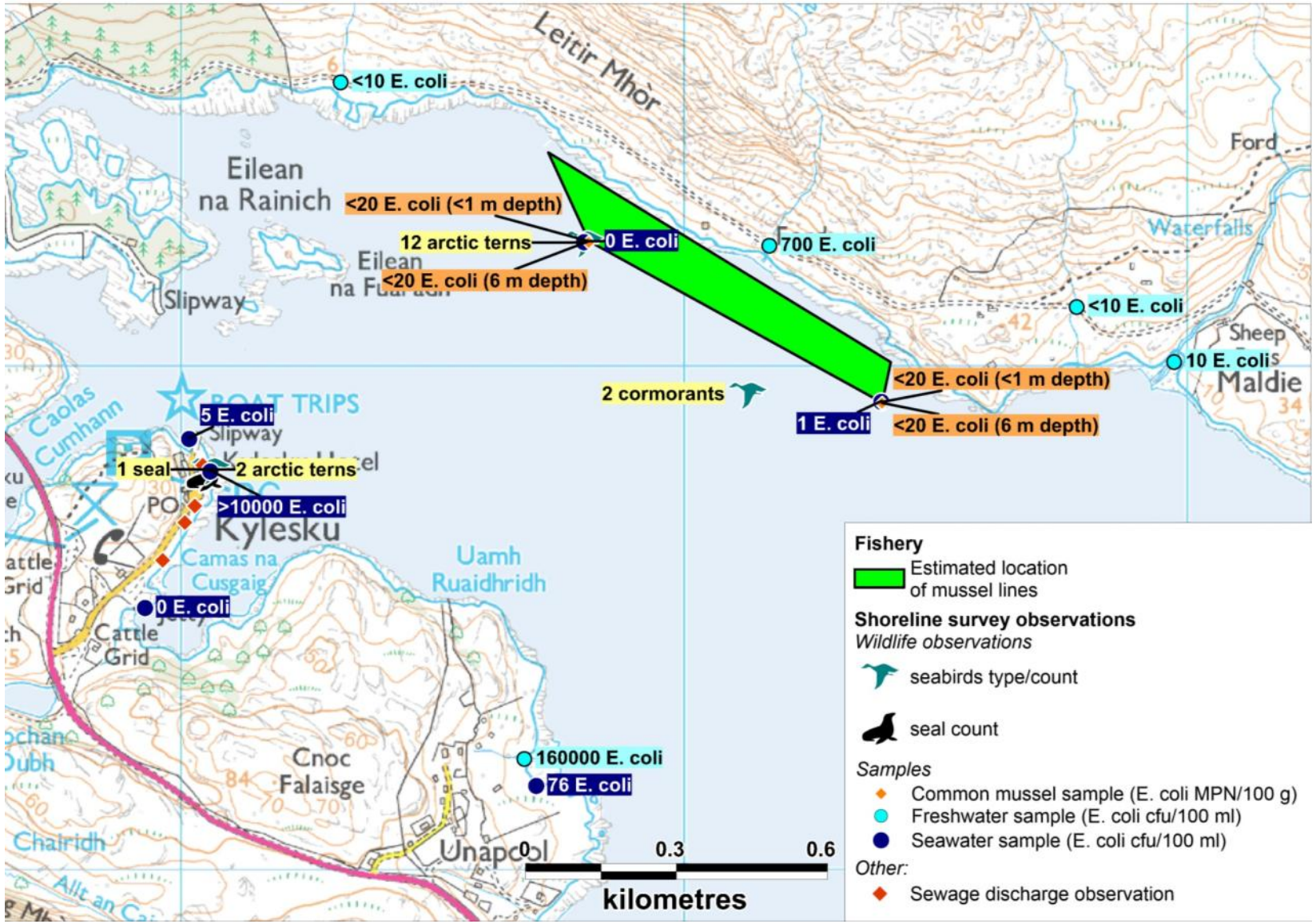


Figure 14.1 Map of principal shoreline survey observations at Loch Glencoul

15. Overall Assessment

Human sewage impacts

The nearest noted source of human sewage is the septic tank associated with a construction compound adjacent to Maldie Burn, approximately 700 m E of the mussel farm. If this is still in use, and operating correctly, it should not pose a significant risk of contamination to the fishery. Other sewage discharges are located around small clusters of largely seasonally occupied dwellings at Unapool and Kylesku. These are located approximately 1 km SW of the NW end of the mussel farm. Contamination arising from these sources is likely to be highly seasonal, as many of the dwellings appear to be occupied only during the summer holiday season (May to September).

Agricultural impacts

Agricultural parishes in the area were very large, with relatively low numbers of livestock reported. The land cover in the area is largely heath and rough grassland, with very little in the way of improved grassland and no arable land. The OS 1:25000 map does note sheep pens adjacent to Maldie Burn and Unapool Burn, and cattle grids around Kylesku suggesting that livestock have historically been kept in the area. No evidence of current farming activity was seen during the shoreline survey but the sampling officer identified seeing sheep around the area and pigs at Unapool. The potential for diffuse contamination from agricultural sources in the area is considered to be low.

Wildlife impacts

Little information was available on wildlife sources in the area. Very few animals were noted during the shoreline survey. It is likely that deer and other wildlife animals present in the catchments will contribute the majority of faecal contamination found in the local watercourses such as Allt Briste and Maldie Burn. Seals are noted to be present to the west of the shellfishery and are most likely to be present from May to August, when they give birth and rear pups.

Birds such as eider ducks, cormorants and gulls are likely to be present on or near the mussel farm, and these may leave droppings directly on or near the mussel lines. However, there is no evidence to suggest one part of the mussel farm may be more affected than another.

Seasonal variation

Seasonal variation was evident in the historical monitoring results, which showed a marked increase in results between June and August. This broadly coincides with the predicted increase in human occupation in the area, the period when seals are likely to be present west of the mussel farm, the period with lowest daily rainfall, and the period when southerly winds are more frequent.

Rivers and streams

Three watercourses enter the loch within <500 m of the mussel farm; Maldie Burn, Allt Briste, and an unnamed watercourse. These are expected to have a moderate impact on the microbiological quality of water at the mussel farm. The loadings of faecal indicator bacteria carried in these watercourses would be expected to be higher after rainfall than those estimated from the measurements made during the shoreline survey, which was undertaken in dry weather.

The predominant sources within the watercourse catchments are likely to be wildlife.

Movement of contaminants

Surface contaminants, such as faecal indicator bacteria arising in freshwaters or deposited at the surface, are likely to be transported less than 1 km, primarily along the axis of the loch. Therefore, it is most likely that sources arising within a short distance to the east and west of the mussel farm will be most likely to impact the bacteriological quality of the mussels there. To the west of the mussel farm are an anchorage area, that is most likely to be used intermittently during the summer and an area used by seals. Any contamination arising from these sources is most likely to affect the western side of the fishery.

Analysis of historical monitoring results showed higher results tended to occur on increasing and ebb tides. This suggests that the most significant sources of faecal contamination to the fishery are those to the east of the mussel farm.

To the east of the mussel farm, any faecal contaminants carried via Maldie Burn would have the greatest impact the east side of the mussel farm whilst those carried via Allt Briste would impact along the north central part of the mussel farm.

Temporal and geographical patterns of sampling results

There has been no marked temporal change in sampling results over the period analysed (2008-2013), although there has been a decrease in the magnitude of results over time.

The majority of samples were recorded as having been taken within 100 m of the nominal RMP. The location of the highest recorded sample result coincides with the southern edge of the current mussel farm location, north of the nominal RMP. No samples were reported from the east or west extents of the mussel farm. Samples taken during the shoreline survey from these extents returned results below the limit of detection. The nominal RMP is located south of the mouth of Allt Briste, which is the closest potential source of faecal contamination to the fishery.

Conclusions

Seasonal variation in historical monitoring results suggests that highest contamination levels occur during the summer months. This coincides with the presence of known sources, such as septic tank outfalls around Kylesku and Unapool and seals to the west of the mussel farm. However it also coincides with drier weather, when rainfall events may result in flushes of faecal contaminants to watercourses. The predicted movement of contaminants suggests that the human sewage sources south of the fishery are unlikely to significantly affect water quality there, and that sources arising within 500 m of the fishery are more likely to have an impact. The primary sources within the range of the mussel farm are watercourses along the north shore of the loch. Of these, Allt Briste lies in closest proximity to the mussel farm, and though its loading was estimated to be relatively low the water sample on which this calculation was based returned a result of 600 *E. coli* cfu/100 ml, suggesting moderate faecal contamination. The Maldie Burn had a higher loading, but the *E. coli* result was at the lower limit of detection. This suggests that the higher volume found in Maldie Burn is providing for greater dilution of contaminants.

The additional farm south of the production area boundary is reported by the harvester, and in the planning approval, to be for seed collection only and therefore does not need to be included within the monitored production area.

Overall Risk Table

Risk	
Sewage discharges from septic tanks	Low
Diffuse contamination carried via watercourses	Moderate
Wildlife sources	Low
Seasonal variability	Moderate

16. Recommendations

Production area

As there are no other shellfish production sites within the current production area boundaries, and the new site south of the boundary is for production of seed only, it is recommended that the production area be curtailed to encompass only the area of current production and to exclude sources of faecal contamination. Therefore, it is recommended that the boundaries be amended to the area bounded by lines drawn from NC 2340 3450 to NC 2363 3352 to NC 2439 3310 to NC 2462 3391 and back to NC 2340 3450, extending to MHWS along the northern boundary RMP. This excludes populated areas around Unapool and Kylesku, as well as the mouth of Maldie Burn.

RMP

It is recommended that the RMP be relocated to a position nearer the Allt Briste, on the northern side of the mussel farm. The recommended location is NC 2412 3419.

Tolerance

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

Depth of sampling

As the main potential sources of faecal contamination at this location are likely to be found near the surface, and predation by ducks has been reported to affect the top 1-2 m of line, it is recommended that samples be taken from within the top 3 metre of the lines. If this is not feasible, consideration should be made to placing bagged mussels at the RMP for sampling purposes. If bagged shellfish are used, they should be hung at approximately 1 metre depth and should be in situ for at least two weeks before sampling to ensure that they are representative of the conditions at the site.

Frequency

Monitoring should be undertaken on a monthly basis throughout the year due to the variable trend in monitoring results seen across months.

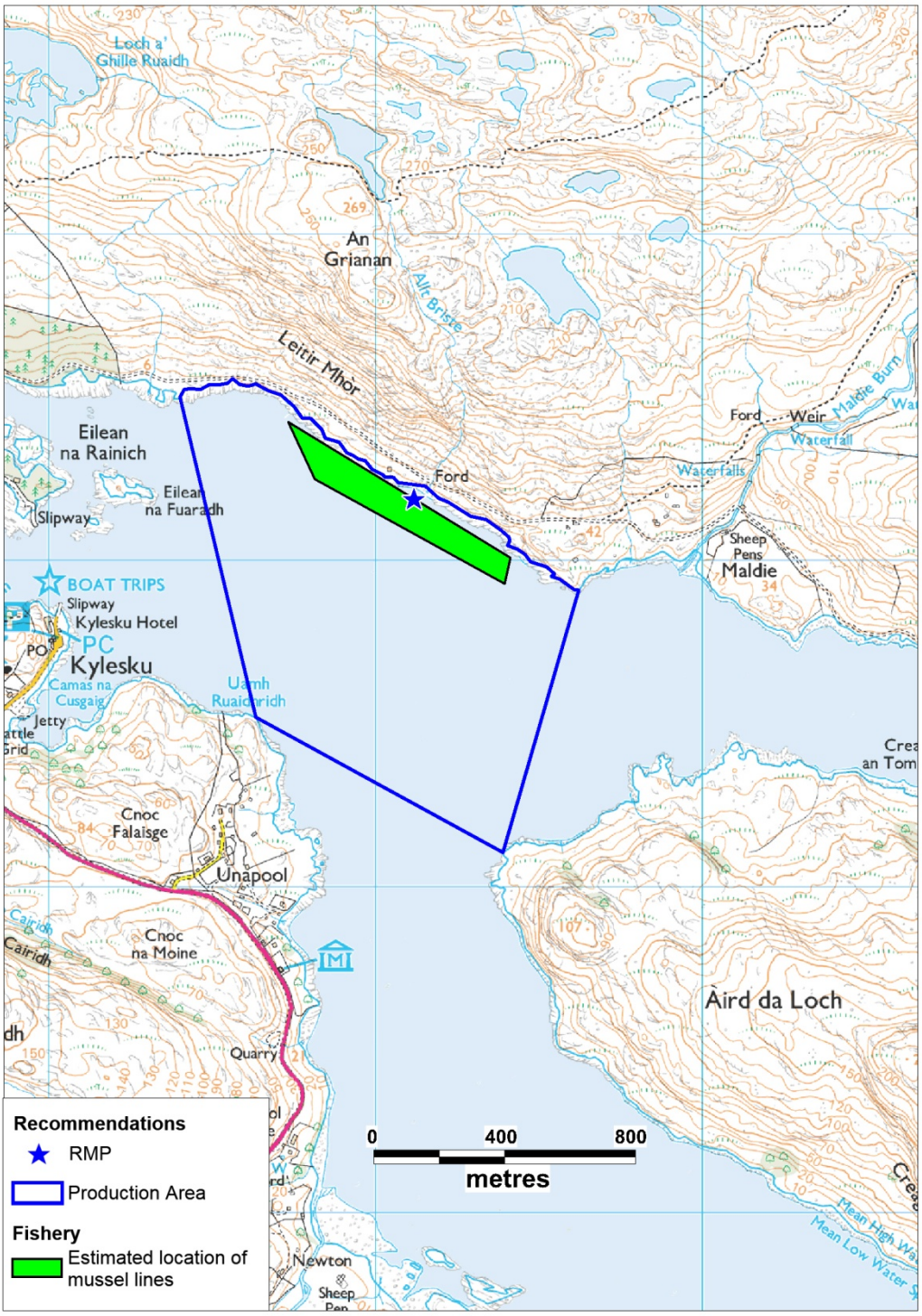


Figure 16.1 Map of recommendations at Loch Glencoul

17. References

Ash Design Assessment, 2009. *Maldia Burn Hydroelectric Scheme,* s.l.: Ash Design Assessment.

Barne, J. H. et al., 1997. *Coasts and Seas of the United Kingdom Regions 15 & 16 North-West Scotland: The Western Isles and West Highland,* Peterborough: Joint Nature Conservation Committee (Coastal Directories Series).

Bell, C. & Carlin, L., 1998. Generation of UK tidalstream atlases from regularly gridded hydrodynamic moddelled data.. *Journal of Navigation,* 51(1), pp. 73-78.

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

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

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

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

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

Kylesku Lodges, http://www.kyleskulodges.co.uk/self-catering-accommodation.htm. Accessed 05/09/2013.

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

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

Newton Lodge, 2013. *Mammals, Birds and Where to Watch Birds.* [Online] Available at: http://www.newtonlodge.co.uk/wildlife.htm [Accessed 02 09 2013].

Scottish National Heritage, 2013. *Otters.* [Online] Available at: http://www.snh.gov.uk/about-scotlands-nature/species/mammals/land-mammals/otters/ [Accessed 02 09 2013].

SEPA, 2011. *Loch Glencoul Shellfish Growing Water Report,* Sterling: SEPA.

Special Committee on Seals, 2012. *Scientific Advice on Matters Related to the Management of Seal Populations 2012,* St Andrews: St Andrews University; Sea Mammal Research Unit.

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**
5. **Shoreline Survey Report**

1. General Information on Wildlife Impacts

Pinnipeds

Two species of pinniped (seals, sea lions, walruses) are commonly found around the coasts of Scotland: These are the European harbour, or common, seal (*Phoca vitulina vitulina*) and the grey seal (*Halichoerus grypus*). Both species can be found along the west coast of Scotland.

Common seal surveys are conducted every 5 years and an estimate of minimum numbers is available through Scottish Natural Heritage.

According to the Scottish Executive, in 2001 there were approximately 119,000 grey seals in Scottish waters, the majority of which were found in breeding colonies in Orkney and the Outer Hebrides.

Adult Grey seals weigh 150-220 kg and adult common seals 50-170 kg. They are estimated to consume between 4 and 8% of their body weight per day in fish, squid, molluscs and crustaceans. No estimates of the volume of seal faeces passed per day were available, though it is reasonable to assume that what is ingested and not assimilated in the gut must also pass. Assuming 6% of a median body weight for harbour seals of 110kg, that would equate to 6.6kg consumed per day and probably very nearly that defecated.

The concentration of *E. coli* and other faecal indicator bacteria contained in seal faeces has been reported as being similar to that found in raw sewage, with counts showing up to 1.21×10^4 CFU (colony forming units) *E. coli* per gram dry weight of faeces (Lisle *et al* 2004).

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

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

Cetaceans

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

A variety of cetacean species are routinely observed around the west coast of Scotland. Where possible, information regarding recent sightings or surveys is gathered for the production area. As whales and dolphins are broadly free ranging, this is not usually possible to such fine detail. Most survey data is supplied by the Hebridean Whale and Dolphin Trust or the Shetland Sea Mammal Group and applies to very broad areas of the coastal seas.

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

Birds

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

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

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

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

Deer

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

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

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

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

Other

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

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

References

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

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

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

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

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

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

2. Tables of Typical Faecal Bacteria Concentrations

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

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

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

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

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

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

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

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

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

Source: (Gauthier & Bedard, 1986)

References

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

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

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

3. Statistical Data

One-way ANOVA: logec versus Season

```
Source  DF      SS     MS     F      P
Season   3   2.300  0.767  1.75  0.168
Error   54  23.643  0.438
Total   57  25.943

S = 0.6617   R-Sq = 8.87%   R-Sq(adj) = 3.80%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  --------+---------+---------+---------+-
1      16  1.3059  0.4518  (-----------*----------)
2      15  1.8162  0.9107                  (-----------*----------)
3      13  1.5698  0.7451         (-----------*-----------)
4      14  1.3949  0.4213    (----------*-----------)
                           --------+---------+---------+---------+-
                                 1.20      1.50      1.80      2.10

Pooled StDev = 0.6617
Grouping Information Using Tukey Method

Season   N    Mean  Grouping
2       15  1.8162  A
3       13  1.5698  A
4       14  1.3949  A
1       16  1.3059  A

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 = 98.95%


Season = 1 subtracted from:

Season    Lower  Center   Upper  --------+---------+---------+---------+-
2       -0.1203  0.5103  1.1408                (----------*---------)
3       -0.3912  0.2639  0.9190           (----------*----------)
4       -0.5531  0.0890  0.7311         (---------*----------)
                                --------+---------+---------+---------+-
                                     -0.60      0.00      0.60      1.20


Season = 2 subtracted from:

Season    Lower   Center   Upper  --------+---------+---------+---------+-
3       -0.9112  -0.2464  0.4185     (----------*----------)
4       -1.0732  -0.4212  0.2308  (----------*----------)
                                 --------+---------+---------+---------+-
                                      -0.60      0.00      0.60      1.20

Season = 3 subtracted from:

Season    Lower   Center   Upper  --------+---------+---------+---------+-
4       -0.8507  -0.1749  0.5009      (----------*----------)
                                 --------+---------+---------+---------+-
                                      -0.60      0.00      0.60      1.2
```

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

Document Number	B0067_Shoreline 0014

Revision History

Revision	Changes	Date
A	Issue for internal review	18/07/2013
01	Formal issue to CEFAS	19/07/2013
02	Second issue to CEFAS addressing comments at Rev 01	06/08/2013
03	Method of calculating estimated flow rate added to observation table.	07/08/2013

	Name & Position	Date
Author	Debra Brennan	17/07/2013
Checked	Andrea Veszelovszki, Mark Hart	02/08/2013
Approved	John Hausrath	07/08/2013

This report was produced by SRSL for its Customer for the specific purpose of providing a shoreline survey report for Loch Glencoul as per the Customer's requirements. This report may not be used by any person other than SRSL's Customer without its express permission. In any event, SRSL accepts no liability for any costs, liabilities or losses arising as a result of the use of or reliance upon the contents of this report by any person other than its Customer.

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Shoreline Survey Report

Production area:	Loch Glencoul
Site name:	Kylesku
SIN:	HS-157-310-08
Species:	Common Mussels (*Mytilus edulis)*
Harvester:	John Ross
Local Authority:	Highland Council: Sutherland
Status:	Existing area
Date Surveyed:	09/07/2013
Surveyed by:	Debra Brennan and Colin Abernethy
Existing RMP:	NC2407 3406

Area Surveyed

Shellfish samples were taken from the west and east side of the mussel lines. The shoreline was surveyed for approximately 0.5km south west from the starting position at Kylesku slipway. Approximately 0.2 km of shoreline was surveyed at Unapool (difficulty with access prevented the entire shoreline on the survey plan to be conducted). Approximately 3.5km of shoreline was surveyed on the North side of the loch from the Reay Forest Estate headquarters to Maldie Burn.

Weather

There was no rainfall recorded for the previous week (from 02/07/2013) leading up to the survey. The weather was mostly dry and sunny with 80% cloud cover on the morning of the survey. Wind speed 7.9 km/h. Sea state 1, calm rippled. Cloud cover remained constant for the majority of the survey, with very light misty rain and a brief shower at 14.00 hours.

Stakeholder engagement during the survey

The harvester for Loch Glencoul, John Ross, was extremely cooperative and helpful both during survey preparations and during the survey itself, providing boat access and being present on the day of the survey.

Anne Grant, the local sampling officer for the Sutherland area was also very helpful during preparations for the survey, and met with the team on-site during the survey.

Fishery

Loch Glencoul is a common mussel (*Mytilus edulis)* fishery on a Crown Estate seabed lease. The fishery consists of a well-established site on the northeast shore of the loch which is generally harvested every year in July and August

only. Mussels are grown on suspended culture lines with each individual line being approximately 6-8m depth.

The harvester noted the recent, unusual occurrence of biotoxins in the loch which led to the closure of the site during the survey. He also reported the presence of jellyfish in the production area in higher than usual numbers and the fact that Eider ducks are a problem predating on the mussel lines.

The harvester supplied additional information on a newly established site with four lines of 300 m on the southeast part by the head of the loch which is only used for spat collection at present. Spat settlement in Loch Glencoul in general is found to be sporadic. This site was not visited during the survey. At the time of survey, the harvester had no plans for the fishery to undergo any spatial changes in the near future.

It was also noted by the sampling officer that mussel harvesting had recently been closed down temporarily during the construction of a new hydroelectric facility on the North East side of the loch (see land use below).

Sewage Sources

The area surrounding the loch is predominantly unpopulated. The small settlement close to slipway at Kylesku consists of approximately 10 private dwellings, 1 hotel and a public toilet facility. An actively flowing sewage pipe was observed from the public toilet facility discharging into the loch where an additional seawater sample was taken (waypoints 13 and 14). There is another small settlement of approximately 12 dwellings at Unapool and on the north shore of the loch there is a complex of estate buildings on the Reay Forest Estate where a private road runs parallel to the loch for approximately 3km to the Hydro facility.

Seasonal Population

There are 10 holiday lodges and 1 hotel at Kylesku. The Reay Forest Estate is used for sporting and has guest accommodation but this is not located around the shore of Loch Glencoul.

Boats/Shipping

Three piers or slipways were observed during the survey. These are mostly used for the boats working on the mussel lines, for tourist trips up the loch towards the waterfalls, or for pleasure fishing. On the day of the survey, there was one pleasure fishing boat close to Kylesku slipway preparing to go out for the day.

Farming and Livestock

There was a sparse population of sheep. The scattered populations consisted of no more than 30 sheep in total, observed during the length of the survey. They were noted generally in the surrounding area of the loch but not directly in the area of the shoreline.

Land Use

Land use on the north side of the loch was predominantly private estate for shooting and fishing. On the southern side of the loch, land use was mostly plantation forestry. A few small settlements were scattered around the West side of the loch. There was a RWE Npower Renewables Ltd (RNE) hydroelectric facility at the North East side of the loch, which consists of a semi-buried power-house (housing a turbine, generator and associated equipment) with a buried pipe running from the intake weir to the power house.

Land Cover

Most of the immediate land surrounding the Loch was steep and hilly to mountainous with rocky shoreline bordering the majority of the loch perimeter.

The predominant land cover was plantation forestry to the south east side of the survey area and rough grazing land elsewhere.

Watercourses

There are five main watercourses within the survey area, two of which are less than 1m in width .The other three are: Unapool Burn (near Unapool), Allt Bristle and Maldie Burn (latter two on the north side of the loch). Maldie Burn enters the loch from the Eas a' Chuall Aluinn waterfall adjacent to the hydroelectric facility 3 km East of Kylestrome.

Wildlife/Birds

There were a number of Arctic terns observed during the survey flying around the area of the mussel lines. There was evidence of Eider ducks at the mussel lines, with the harvester explaining that they predate on the top metre or so of mussels. This was evident as the flotation barrels were high in the water and it could be seen that the top sections of the lines had been re-colonised by hundreds of very small mussels. Eider ducks however were not seen on the day of the survey. There were two cormorants observed on the flotation barrels. A common seal was also seen. The harvester reported seeing a pair of golden eagles regularly around the survey area but they were not observed on the day of the survey. The survey team met an ecologist performing an otter survey around the loch. At the time of the meeting the

otter survey had just begun, and the ecologist did not yet know whether there were any otters present in the area.

Shoreline Survey Maps

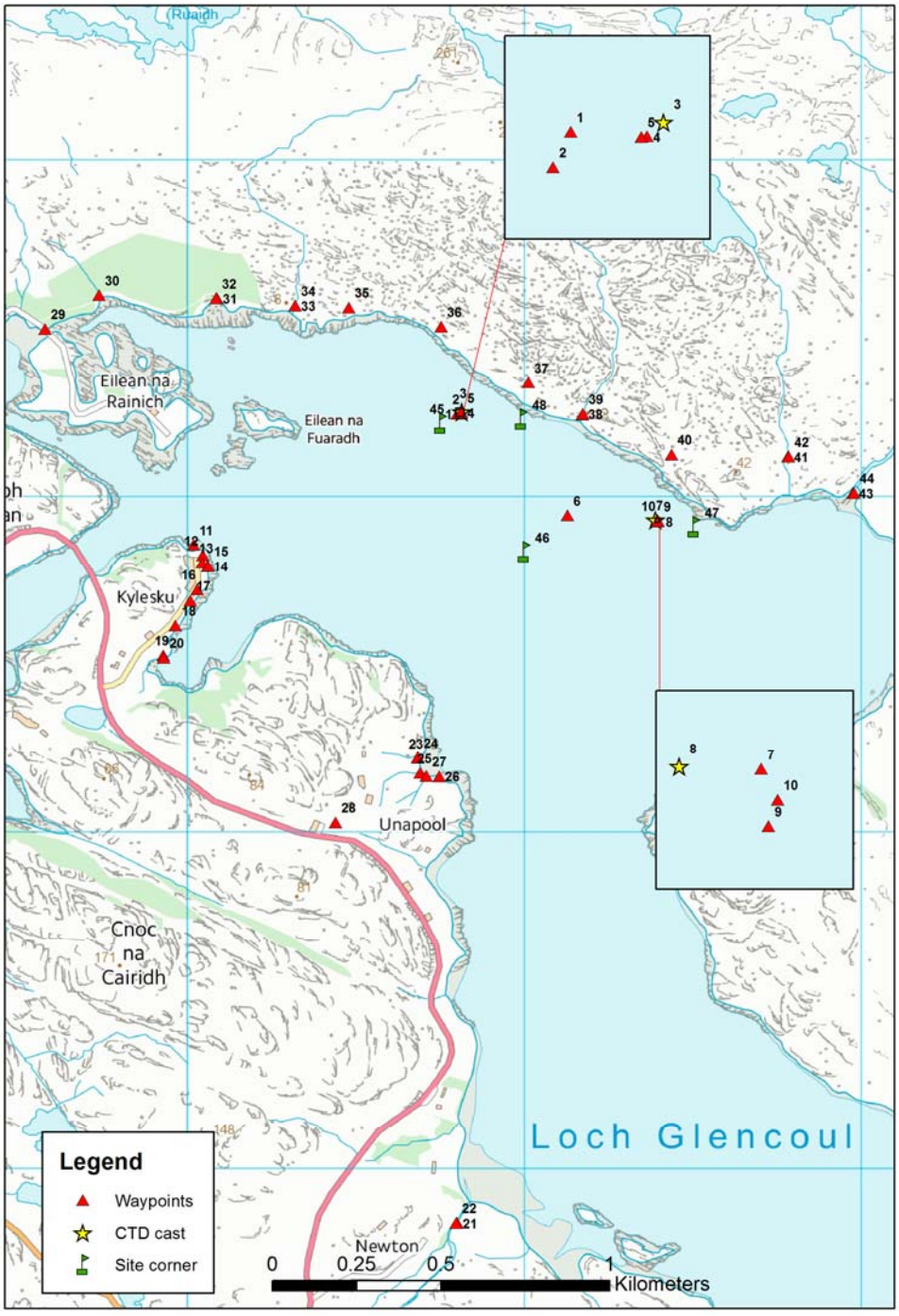

Figure 1. Map of Loch Glencoul waypoints

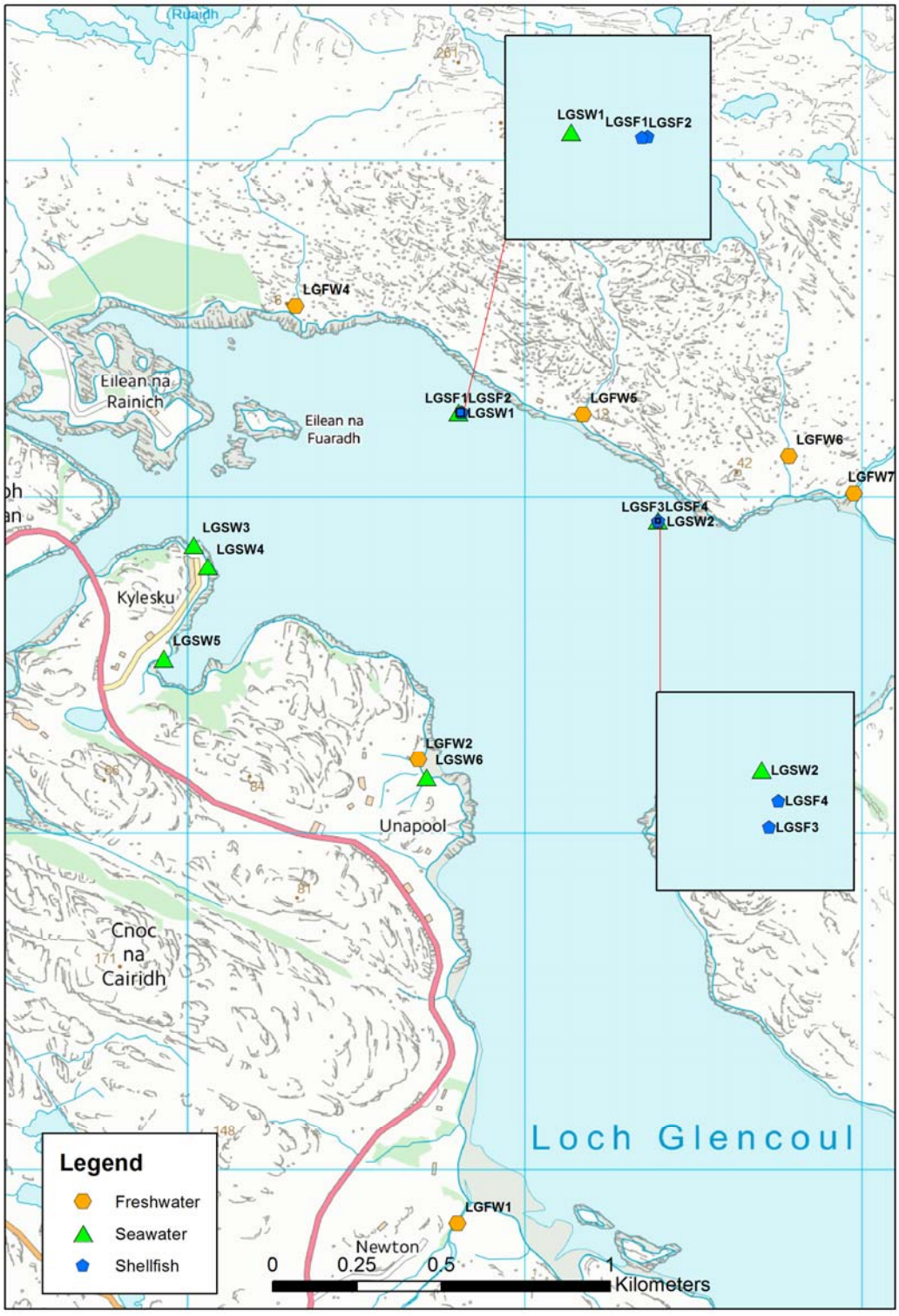

Figure 2. Map of Loch Glencoul samples

Table 1 Shoreline Observations.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description	Sample Type
1	09/07/2013	8:49	NC 23803 34248	223804	934249		LGSW1	Planned seawater sample LGSW1 taken from boat.	Seawater
2	09/07/2013	8:50	NC 23801 34244	223802	934245			12 Arctic Terns spotted.	
3	09/07/2013	8:52	NC 23814 34249	223815	934250			CTD cast 1.	
4	09/07/2013	8:55	NC 23812 34248	223813	934248		LGSF1	NW end of mussel farm. Planned shellfish sample LGSF1 taken from a depth of approximately 1m.	Shellfish
5	09/07/2013	8:56	NC 23812 34248	223812	934248		LGSF2	Planned Shellfish sample LGSF2 taken from same line as LGSF1 at a depth of approximately 6m.	Shellfish
6	09/07/2013	9:00	NC 24127 33943	224128	933944			Bird count: 2 Cormorants sat on mussel lines.	
7	09/07/2013	9:03	NC 24394 33930	224395	933931		LGSW2	Planned seawater sample LGSW2 taken from boat.	Seawater
8	09/07/2013	9:03	NC 24389 33930	224389	933931			CTD cast 2.	
9	09/07/2013	9:06	NC 24395 33926	224395	933927		LGSF3	South West end of mussel farm. Planned shellfish sample LGSF3 taken from a depth of approximately 1m.	Shellfish

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description	Sample Type
10	09/07/2013	9:06	NC 24395 33928	224396	933929		LGSF4	Planned shellfish sample LGSF4 taken from same line as LGSF3 at a depth of approximately 6m.	Shellfish
11	09/07/2013	9:22	NC 23018 33856	223018	933857		LGSW3	Planned seawater sample LGSW3 taken from boat close to slipway.	Seawater
12	09/07/2013	9:32	NC 23045 33825	223046	933826	Fig 3		Start of shoreline survey. West of slipway, steep rocky shore with grass bank directly above.	
13	09/07/2013	9:34	NC 23044 33803	223045	933804	Fig 4		Manhole covers beside public toilet, pipe running over rocks directly into loch. Strong sewage smell.	
14	09/07/2013	9:38	NC 23060 33792	223061	933793		LGSW4	Unplanned seawater sample LGSW4 taken close to outflow pipe; sample associated with waypoint 13. Sample taken to reflect high risk of contamination.	Seawater
15	09/07/2013	9:39	NC 23061 33793	223061	933794			Two terns flying above water, 1 seal. Clay pipe, diameter 20cm, pipe submerged so no indication of flow.	
16	09/07/2013	9:46	NC 23029 33723	223029	933723	Fig 5		Man hole cover above the shore, pipe running from it under cement covering into loch, not possible to access and sample.	

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description	Sample Type
17	09/07/2013	9:49	NC 23009 33689	223009	933690	Fig 6		Pipe protruding from under the road onto shore. Historical evidence of flow, i.e. staining below outflow but no obvious outflow at time of survey. Unable to access.	
18	09/07/2013	9:52	NC 22965 33615	222965	933615	Fig 7		Pipe on shore, no access, appeared not to be in use.	
19	09/07/2013	9:57	NC 22929 33527	222929	933527			Diesel and oil containers beside jetty.	
20	09/07/2013	9:58	NC 22930 33520	222930	933520		LGSW5	Planned seawater sample LGSW5 taken from jetty.	Seawater
21	09/07/2013	10:48	NC 23800 31840	223800	931841		LGFW1	Planned freshwater sample LGFW1; sample associated with waypoint 20.	Freshwater
22	09/07/2013	10:49	NC 23797 31839	223798	931839			Burn running down to loch, width 3m, 2 depths and flow rates taken. Depth 1: 30cm flow rate 0.973ms^{-1} SD 0.041. Depth 2: 25cm; flow rate 0.557ms^{-1} SD 0.015.	
23	09/07/2013	11:11	NC 23684 33220	223684	933220		LGFW2	Planned fresh water sample LGFW2; sample associated with waypoint 22.	Freshwater
24	09/07/2013	11:12	NC 23684 33222	223684	933222			Burn running down to shore of loch, width 0.25m, depth 1cm, flow rate estimated at approximately 5ml per second, calculated using graduated sample container and wrist watch. 3 houses in proximity, no smell of sewage.	

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description	Sample Type
25	09/07/2013	11:16	NC 23691 33175	223691	933175			Small boat and creels sitting on wooden jetty on shore.	
26	09/07/2013	11:19	NC 23747 33165	223748	933165	Fig 8		Barbed wire fence reaching to end of steep rocks, preventing access to shore for exact location of planned seawater sample LGSW6.	
27	09/07/2013	11:23	NC 23708 33166	223709	933166		LGSW6	Seawater sample LGSW6 planned (at different location to survey plan map).	Seawater
28	09/07/2013	11:33	NC 23440 33029	223440	933029			Access to planned freshwater sample also hindered as for waypoint 26 and private properties above the steep banks further prevented access to the sample location.	
29	09/07/2013	11:50	NC 22578 34497	222578	934498	Fig 9/10		Photographs taken to demonstrate the difficulty and/or danger of access. Dense tree line, steep slippery, rocky shore.	
30	09/07/2013	11:54	NC 22738 34597	222739	934598			Freshwater course running under road, no sample required on survey map. Sample not taken as watercourse deemed low risk.	
31	09/07/2013	12:00	NC 23087 34588	223088	934588			Small watercourse running under road onto shore. Low risk: no sample taken.	

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description	Sample Type
32	09/07/2013	12:00	NC 23085 34588	223086	934588			Watercourse observations: width: 0.2m; depth: 1.5 cm; estimated flow: 10ml/sec, calculated using graduated sample container and wrist watch.	
33	09/07/2013	12:06	NC 23319 34566	223320	934566		LGFW4	Planned Freshwater sample LGFW4; sample associated with waypoint 34.	Freshwater
34	09/07/2013	12:06	NC 23320 34566	223320	934567			Watercourse running from hill under road to shore. Width approximately 1m, depth 3cm, flow estimated at approximately 15 ml/sec, calculated using graduated sample container and wrist watch.	
35	09/07/2013	12:11	NC 23479 34561	223479	934561			Steep ground no access to shoreline.	
36	09/07/2013	12:14	NC 23753 34504	223753	934504			NW end of mussel lines observed from road above inaccessible shore. Nine mussel lines in view.	
37	09/07/2013	12:19	NC 24012 34338	224013	934338			View of mussel line from road. Harvester's boat out on line.	
38	09/07/2013	12:23	NC 24171 34241	224172	934242		LGFW5	Planned Freshwater sample LGFW5 from Allt Bristle; sample associated with waypoint 39.	Freshwater

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description	Sample Type
39	09/07/2013	12:24	NC 24173 34244	224174	934245			Watercourse running across road down to shore, steep inaccessible ground, sample acquired shore side of road. Width approximately 2m Depth 0.5cm. Flow estimated at approximately 20ml/sec, calculated using graduated sample container and wrist watch.	
40	09/07/2013	12:31	NC 24436 34124	224436	934124	Fig 11		Western end of mussel lines, taken from road above shore.	
41	09/07/2013	12:36	NC 24782 34119	224783	934120		LGFW6	Planned Freshwater sample LGFW6; sample associated with waypoint 42.	Freshwater
42	09/07/2013	12:37	NC 24784 34117	224784	934118	Fig 12		Fast running watercourse coming from 2 pipes set into hillside higher up the hill flowing down under a bridge under the road down to the shore.	
43	09/07/2013	12:45	NC 24976 34010	224976	934010		LGFW7	Planned freshwater sample LGFW7; sample associated with waypoint 44.	Freshwater
44	09/07/2013	12:45	NC 24977 34010	224978	934010	Fig 13		Large river running down from waterfalls, alongside the Hydro facility into the loch. No outflow pipes from the hydro visible. Width approximately 5m. Depth 30cm, estimated flow approximately 0.5m/sec, calculated using graduated sample container and wrist watch.	

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description	Sample Type
45			NC 24174 34125	224175	934125			Harvester supplied data on outer boundary of the farm.	
46			NC 24125 34039	224126	934039			Harvester supplied data on outer boundary of the farm.	
47			NC 24408 33869	224408	933870			Harvester supplied data on outer boundary of the farm.	
48			NC 24451 33952	224452	933952			Harvester supplied data on outer boundary of the farm.	

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

Sampling

Water samples were collected at the sites marked on the Loch Glencoul samples map shown in Figure 2.

All the samples were transferred to a Biotherm 10 or Biotherm 30 box with ice packs and posted to the Glasgow Scientific Services (GSS) for *E.coli* analysis. All the samples were posted on the day of collection and all the samples were received the following day. The sample temperatures on arrival at the laboratory were recorded at 3.4°C.

LGSW4 was an extra sample acquired which was not on the sample plan, taken close to the outflow pipe from the vicinity of the public toilet.
LGSW6 was taken but because of restricted access to the shoreline it was not acquired from exact location as on the plan but as close as possible.
Sample at location NC 23440 33029 was not obtained as team could not gain access to this sample point from either side due to barbed wire fence over steep rocky shore with private land above shoreline. The sample reference number LGFW3 was not used during the survey, due to mislabelling, with sample references continued on from LGFW4.

Seawater samples were tested for salinity by GSS and the results were reported in mg Chloride per litre. These results have been converted to parts per thousand (ppt) using the formula:

$$\text{Salinity (ppt)} = 0.0018066 \text{ X } Cl^{-} \text{ (mg/L)}$$

Table 2. Water Sample Results

(NB – the sample number LGFW3 was not used during the survey – see Sampling section above).

No.	Date	Sample	Grid Ref	Type	E. coli (cfu/100ml)	Salinity (ppt)
1	09/07/2013	LGFW1	NC 23800 31840	Freshwater	10	
2	09/07/2013	LGFW2	NC 23684 33220	Freshwater	160000	
3	09/07/2013	LGFW4	NC 23319 34566	Freshwater	<10	
4	09/07/2013	LGFW5	NC 24171 34241	Freshwater	700	
5	09/07/2013	LGFW6	NC 24782 34119	Freshwater	<10	
6	09/07/2013	LGFW7	NC 24976 34010	Freshwater	10	
7	09/07/2013	LGSW1	NC 23803 34248	Seawater	0	35.95
8	09/07/2013	LGSW2	NC 24394 33930	Seawater	1	36.49
9	09/07/2013	LGSW3	NC 23018 33856	Seawater	5	35.77
10	09/07/2013	LGSW4	NC 23060 33792	Seawater	>10000	35.59
11	09/07/2013	LGSW5	NC 22930 33520	Seawater	0	35.05
12	09/07/2013	LGSW6	NC 23708 33166	Seawater	76	33.42

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	Sample depths	E. coli (MPN/100g)
1	09/07/2013	LGSF1	NC 23812 34248	Common Mussel	~ 1m	<20
2	09/07/2013	LGSF2	NC 23812 34248	Common Mussel	~ 6m	<20
3	09/07/2013	LGSF3	NC 24395 33926	Common Mussel	~ 1m	<20
4	09/07/2013	LGSF4	NC 24395 33928	Common Mussel	~ 6 m	<20

Salinity Profiles

Salinity profiles were taken at two locations in the production area, one at each end of the mussel lines. The gathered data will be sent to customer as agreed previously on a separate Excel sheet.

Photographs

Figure 3. Kylesku pier looking over to Reay Private Estate.

Waypoint 12.

Figure 4. Public toilet facility at Kylesku. Waypoint 13.

Figure 5. Manhole cover with pipe. Waypoint 16.

Figure 6. Pipe from under road, historical evidence of flow. Waypoint 17.

Figure 7. Piece of pipe on shore. No access to it due to steep shoreline. Appeared to be not in use. Waypoint 18.

Figure 8. Unable to access shore past this point for freshwater sample at Unapool. Waypoint 26.

Figure 9. Steep rocky shoreline on the north-west side of Loch. Waypoint 29.

Figure 10. Illustrating steepness of shoreline. Waypoint 29.

Figure 11. Loch Glencoul Mussel lines. Waypoint 40.

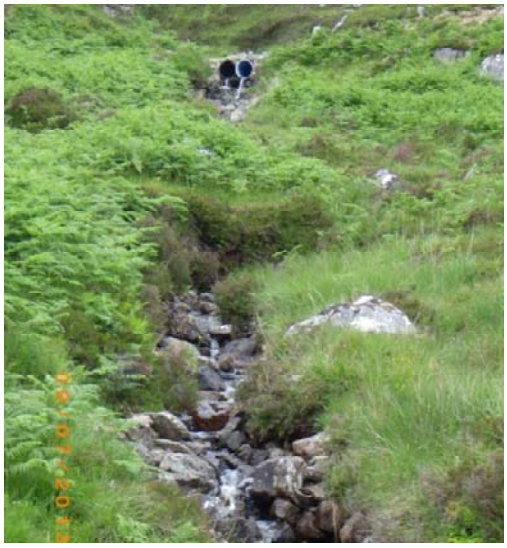

Figure 12. Two pipes under service road above sample site LGFW7. Waypoint 42.

Figure 13. Maldie Burn and Npower hydroelectric facility. Waypoint 44.