Scottish Sanitary Survey Report

Sanitary Survey Report
Loch Ewe and Loch Thurnaig
RC-142
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Partner Organisations

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

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Appendices

I. Executive Summary

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

The purpose of the sanitary survey is to demonstrate compliance with the requirements stated in Annex II (Chapter II Paragraph 6) of Regulation (EC) 854/2004. The sanitary survey results in recommendations on the location of RMPs, the frequency of sampling for microbiological monitoring, and the boundaries of the production areas deemed to be represented by the RMPs. A sanitary survey was undertaken on the classified mussel fishery at East Loch Tarbert on the basis recommended in the European Union Reference Laboratory publication: "Microbiological Monitoring of Bivalve Mollusc Harvesting Area Guide to Good Practice: Technical Application" (https://eurlcefas.org/media/13831/gpg_issue-5_final_all.pdf).

Loch Ewe and Loch Thurnaig are located on the northwest coast of Scotland. Loch Thurnaig is essentially part of Loch Ewe. A ranched scallop fishery takes place in an area covered by a several order. Stock is supplemented from juveniles grown in trays on longlines in a seabed lease area within the several fishery area. A sanitary survey was undertaken at this area on the basis of a risk ranking of those production areas in Scotland that had not yet been subject to a sanitary survey.

The main sources of faecal contamination around Loch Ewe are discharges associated with two community sewerage networks as well as a large number of private septic tanks. While the continuous community discharges are not anticipated to impact to any extent at the fishery, some of the intermittent discharges located on the eastern mainland, together with several private discharges, are located much closer to it. Additional inputs to the loch are watercourses, mainly located on the mainland, and boating activity. A watercourse located on the Isle of Ewe will contribute *E. coli* to the fishery. No information was available on the fate of septic waste associated with houses located adjacent to the fishery on the southeastern side of the island, or on whether any agricultural activities are currently undertaken on the fields located in that area. Seabirds are the main wildlife in the area and may add to background levels of contamination.

Currents in the area are likely to follow the bathymetry of the loch. The predicted particle transport distance of a single phase of a tidal cycle is approximately 3.6 km. However, dispersion assessments undertaken for Scottish Water have shown that present community discharges are likely to have been subject to considerable dilution over that distance.

It is recommended that the extent of the production area be reduced in order to exclude the main identified sources of contamination (primarily discharges from the community networks and the larger private discharges) while fully covering the extent of the present several order. It is also recommended that the RMP is moved to the southeast of its present position in order to better reflect potential impacts from sources at the southeastern end of the Isle of Ewe and the water quality data showing higher concentrations of faecal indicator bacteria at that end of the shellfishery.

II. Sampling Plan

Production Area	Loch Ewe & Loch Thurnaig
Site Name	Loch Ewe
SIN	RC-142-250-07
Species	King scallops
Type of Fishery	Dived
NGR of RMP	NG 8580 8867
East	185,800
North	888,670
Tolerance (m)	100
Depth (m)	Not applicable
Method of Sampling	Hand
Frequency of Sampling	Monthly
Local Authority	Highlands Council
Authorised Sampler(s)	Bill Steven
Production Area	The area bounded by lines drawn from NG 8450 9000 to NG 8510 9000 to NG 8670 8800 to NG 8623 8800, and extending to MHWS

IV. Report

1. General Description

Loch Ewe is a sea loch on the western coast of Scotland, situated in the Ross and Cromarty district of the Highland Council.

The loch has a northerly aspect and opens to the Minch. It is approximately 12 km in length and is approximately 5 km at its widest. The small bay called Loch Thurnaig is on the south eastern corner of Loch Ewe. The relatively large Isle of Ewe occupies the centre of the loch.

There is human habitation all around the loch with population centres at Mellon Charles and Aultbea on the eastern shore Poolewe at the head of the loch and Inverasdale and Cove on the western shore.

A sanitary survey was undertaken on the classified fishery at Loch Ewe And Loch Thurnaig on the basis recommended in the European Union Reference Laboratory publication: “Microbiological Monitoring of Bivalve Mollusc Harvesting Area Guide to Good Practice: Technical Application”. This production area was selected for survey at this time based on a risk-based ranking of the area amongst those in Scotland that had yet to receive sanitary surveys.

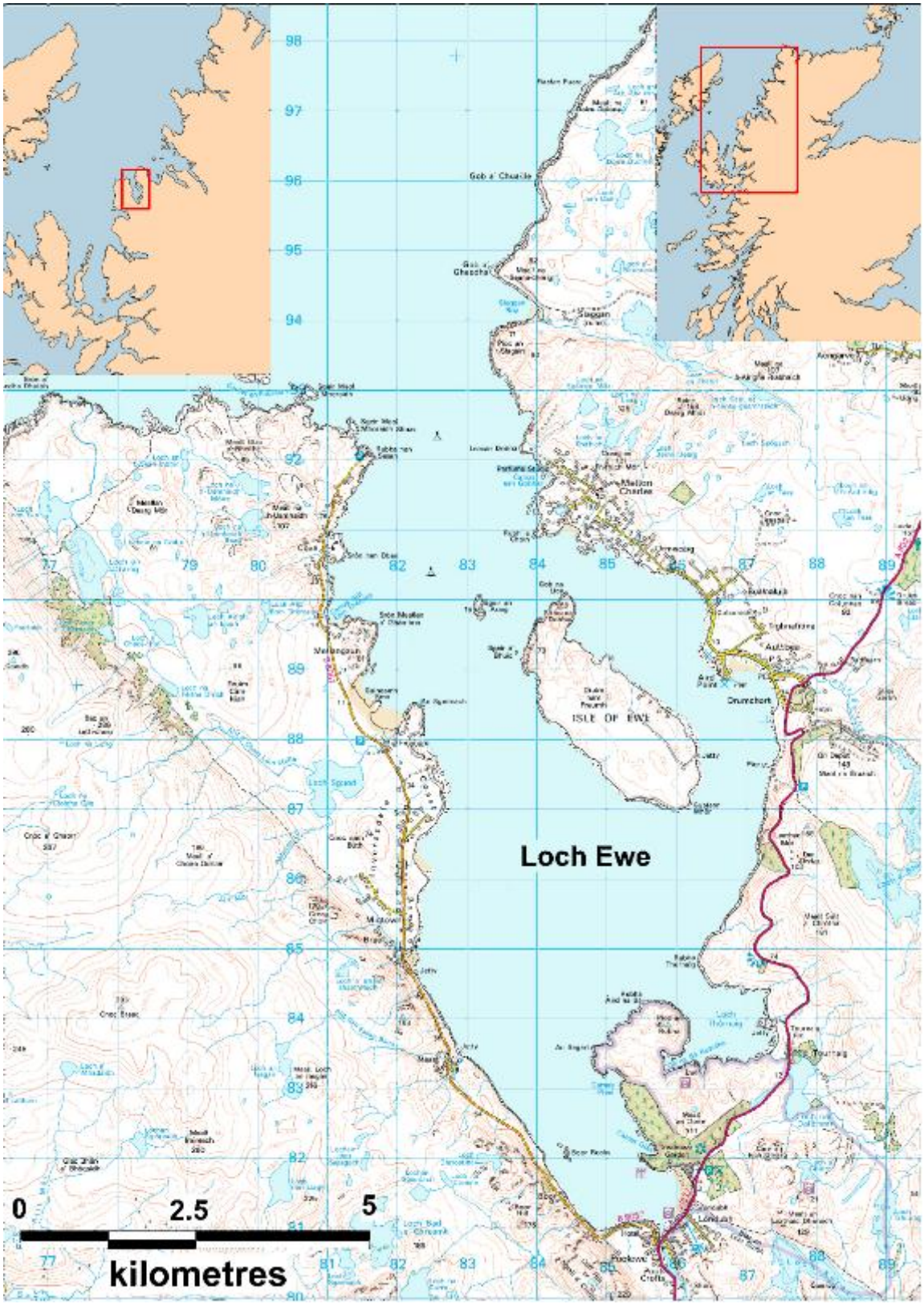


Figure 1.1 Location of Loch Ewe and Loch Thurnaig

2. Fishery

At Loch Ewe, there is a subtidal fishery for King Scallops (*Pecten maximus*), which are harvested by divers. Details of the site given in the 2014-2015 classification document are presented in Table 2.1. There was a mussel fishery in Loch Ewe and Loch Thurnaig, until 2012 when that site was declassified.

Table 2.1 Area shellfish farms

Production area	Site	SIN	Species
Loch Ewe & Loch Thurnaig	Loch Ewe	RC-142-250-07	King Scallop

The production area is presently defined as the area bounded by a line drawn between NG 8164 9200 and NG 8400 9200 extending inshore to MHWS. This covers almost the whole of Loch Ewe and Loch Thurnaig.

The area is subject to a Several Fishery Order. A several order grants ownership of the shellfish specified in the order and gives the owner exclusive right to harvest the shellfish and manage the fishery (GOV.UK, 2013).The several fishery order, laid out in Scottish Statutory Instruments 2013 N.o.280 grants these rights to “Mrs Jane Hardman or Grant”, the present harvester. The several order area is defined as:

> That part of the bed of the sea in Loch Ewe, Wester Ross lying off the north-east shore of the Isle of Ewe, extending to 22.180 hectares or thereby and bounded as follows:–
> on or towards the northwest by a straight line extending in a generally north east direction for 164.778 metres or thereby from a point at 57°50.481’ latitude north and 5°37.318’ longitude west to a point at 57°50.550’ latitude north to a point at 5°37.200’ longitude west -
> then on or towards the north east by a straight line extending in a generally south east direction for 1119.848 metres or thereby to a point at 57°50.140’ latitude north and 5°36.370’ longitude west -
> then on or towards the south east by a line extending in a south westerly direction for 99.983 metres or thereby to a point at 57°50.094’ latitude north and 5°36.429’ longitude west -
> then on or towards the south west by a line following the line of mean low water springs in a generally north westerly direction to the point of beginning.”

The several fishery area is shown in green on the map in Figure 2.1. In addition, an area within the several fishery is the subject of an aquaculture lease for the longline culture of juvenile scallops (area shown in yellow on the map).

At the time of the shoreline survey approximately 100000 young scallops of approximately 3-4 mm size, were suspended in trays from longlines. When of sufficient size these will be released into the fishery area for on-growing and future harvest. The harvester identified that the mature scallops are hand-dived and harvesting may take

place all year round, but that this depends on the maturity of the stock. The harvester mentioned an intention to expand the fishery but whether this related to the fishery area or number of scallops stocked was unclear.

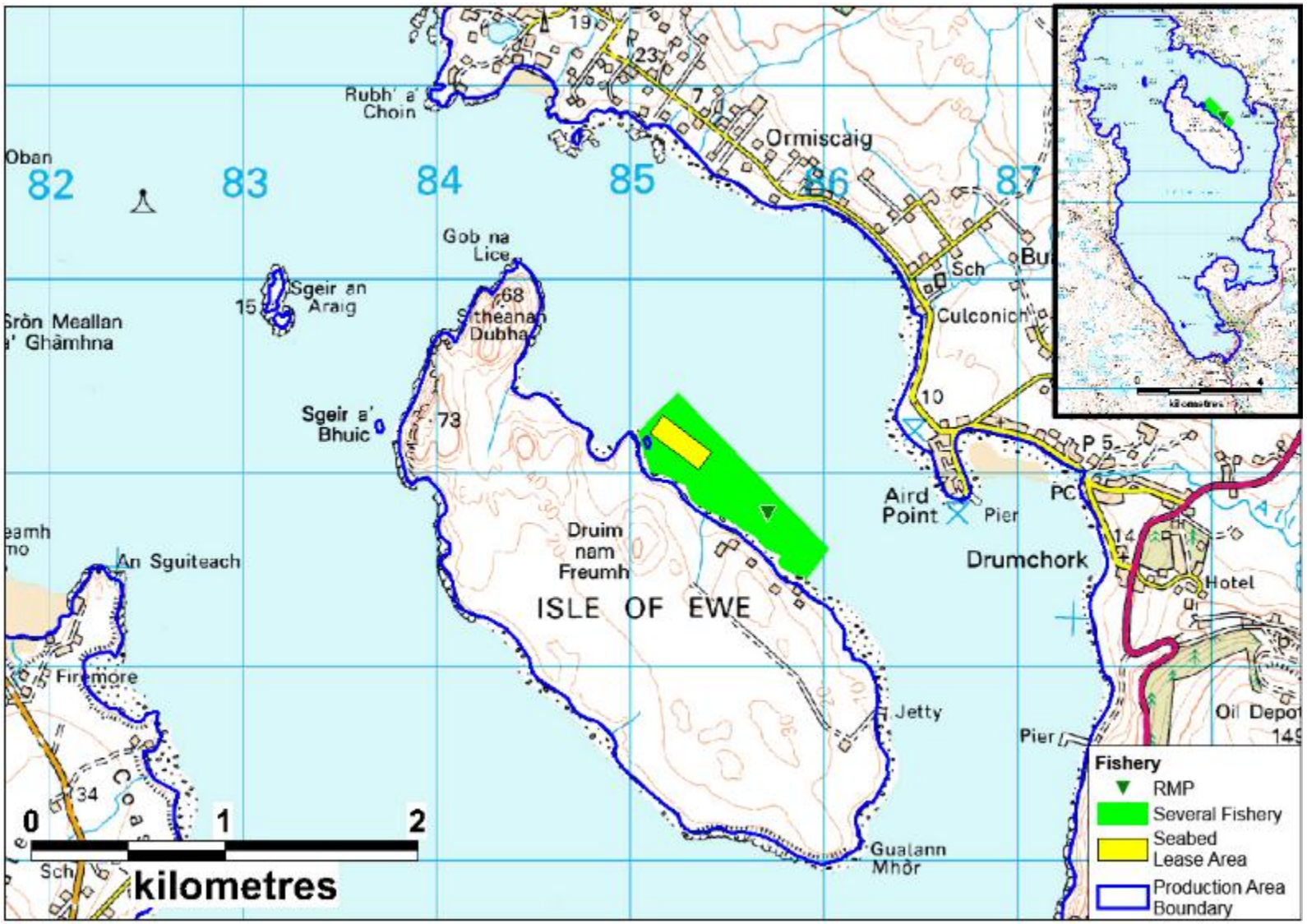


Figure 2.1 Loch Ewe Fishery

3. Human Population

Information was obtained on the population within the vicinity of Loch Ewe and Loch Thurnaig production area from the General Register Office for Scotland. The last census was undertaken in 2011. The census output areas surrounding Loch Ewe and Loch Thurnaig is shown in Figure 3.1 thematically mapped by the 2011 population densities. The population density varies from less than 1 person per km^2 to >60 people per km^2 within the output areas bordering the fishery. However, as the census output areas vary in size and the population within them will not be evenly distributed. The highest population density (106.2 people/km^2) is associated with the census output area around Poolewe at the head of the loch. The second highest population density (61.7 people/km^2) is associated with the census output area around Ormiscaig and Buailnaluib and is located on the mainland directly opposite the fishery. The Isle of Ewe is included in census output area S00081110.

Table 3.1 Census output area and population – Loch Ewe and Loch Thurnaig

Census Output Area ID	Population	Area (km^2)	Population density (People/ km^2)
S00080991	92	3	3.42
S00081478	92	37	2.48
S00081973	152	1	106.2
S00080577	132	238	0.55
S00081110	111	11	10.46
S00081346	85	10	8.56
S00081564	170	62	61.7
S00081660	107	10	10.19
S00081875	104	27	3.84

Small settlements and crofting townships are located along the road running adjacent to the shoreline. The Isle of Ewe is privately owned with several residential dwellings along the eastern coastline adjacent to the several fishery. There is a primary school with 22 pupils on the east side of the loch at Buailaluib (Education Scotland, 2015).

There is a relatively large amount of tourist accommodation in the area, especially in the settlements of Mellon Charles, Aultbea and Drumchork and Poolewe. Additional tourist accommodation is available in the other settlements. Locations of tourist accommodation in the survey area are shown in Figure 3.1.

There are seven anchorages in Loch Ewe, one of which is located off the Isle of Ewe, north of the several fishery and a further two of which are located on the adjacent shoreline north west and south west of the fishery (Clyde Cruising Club, 2007). A jetty is located on the isle of Ewe south of the fishery and additional jetties, piers and slipways are scattered along the loch shore. During the shoreline survey three fishing boats and two smaller boats were observed next to the pier at Aultbea, two boats and a dredger were observed on the shore at Ormiscraig and seven boats were observed north and south of the several fishery.

Overall, the local population on the Isle of Ewe adjacent to the fishery is low but what population is there is principally located adjacent to the edge of the several fishery area. The main concentration of population in the vicinity of the fishery is located on the mainland to the east of the Isle of Ewe, around Mellon Charles, Aultbea and Drumchork. There will also be potential impacts from boats using the area. The presence of tourist accommodation and large number of boating facilities indicate that there is likely to be significant seasonal variation in human population in the area.

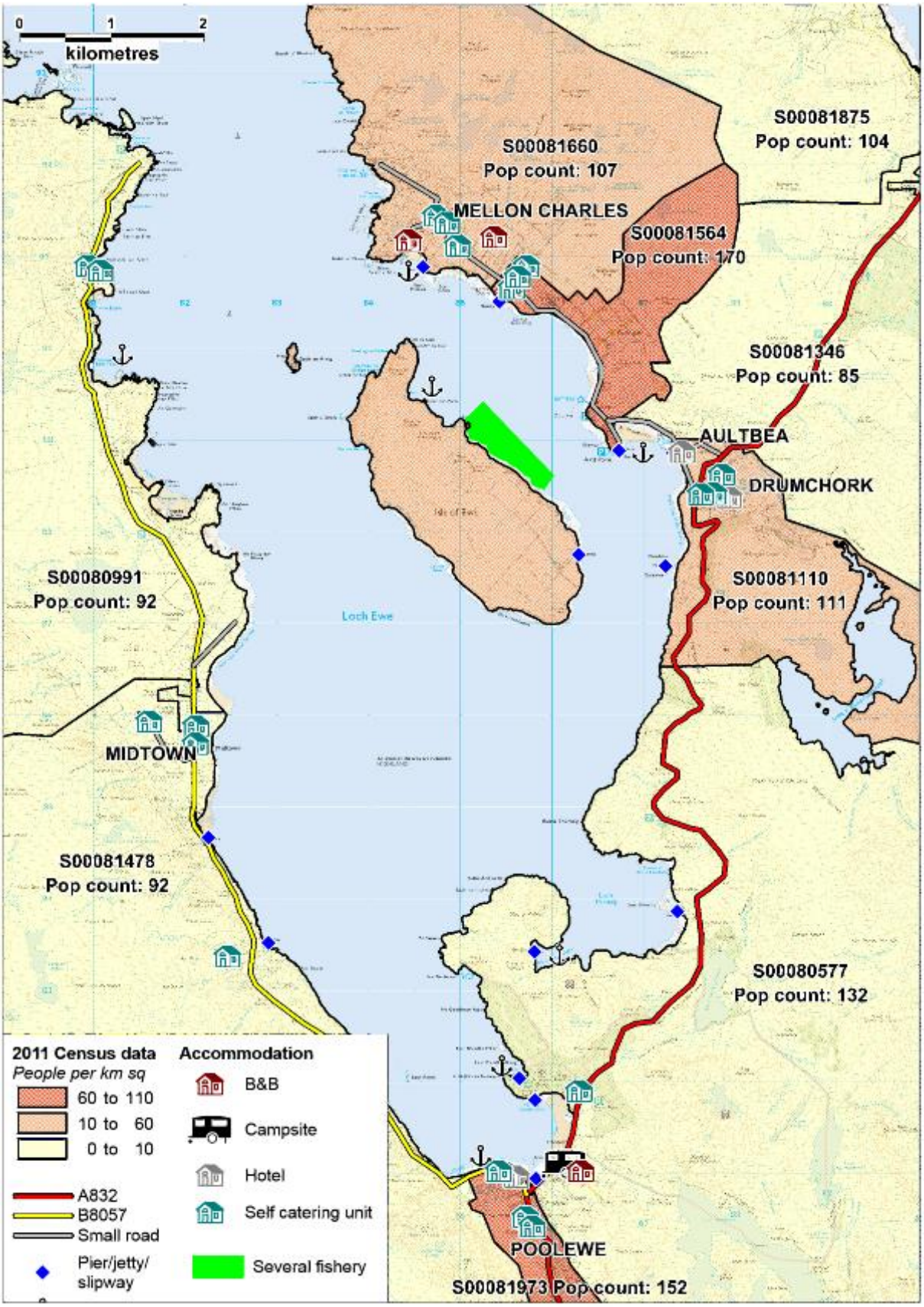


Figure 3.1 Population map for the area around Loch Ewe and Loch Thurnaig

4. Sewage Discharges

Information on sewage discharges within an area of 7 km radius around the point NG 8430 8666 (southwest of the Isle of Ewe) was sought from Scottish Water and the Scottish Environment Protection Agency (SEPA). Data requested included the name, location, type, size (in either flow or population equivalent), level of treatment, sanitary or bacteriological data, spill frequency, discharge destination (to land, watercourse or sea), any available dispersion or dilution modelling studies, and whether improvements were in work or planned.

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

4.1 Community Discharges

There are three community sewage consents for the area of Loch Ewe: one, covering Aultbea and Mellon Charles on the eastern side of the loch (CAR/L/1031729) and two (CAR/L/1040948; final effluent outfalls & CAR/L/1092167; Poolewe sewage network) covering Poolewe at the head of the loch. Information on an additional septic tank (CAR/1001924) was provided by SEPA. This is discussed below with summary information presented in Table 4.1.

A summary of the community discharges are given in Table 4.1. The locations are shown in the maps in Figures 4.1 and 4.2.

Discharge consent CAR/L/1031729 covers eight combined sewer overflows (CSOs), eight emergency overflows (EOs) and one final effluent (FE) outfall. The network serves a population equivalent of 931 and has a consented maximum daily flow of 1512 m^3/day. Predicted spill frequencies were given for the CSOs. Each spill will result in release of untreated effluent, diluted to some extent by rainfall.

SEPA also provided information on Pier Road Septic Tank at Aird (CAR/1001924). The Loch Ewe dispersion study (see Section 4.2) provided by Scottish Water mentions this discharge as having an impact on loadings of faecal coliforms at the fishery. Scottish Water stated that this discharge was replaced by CAR/L/1031729 (removing the discharge) and that the licence has been surrendered. SEPA identified that the licence was still extant. Subsequent to stakeholder consultation on the draft of this report, Scottish Water confirmed that this discharge was no longer active.

Discharge consent CAR/L/1092167 covers four emergency overflows (EOs), and one combined sewer overflow (CSOs). The final effluent outfall is licensed under CAR/L/1040948 and has a PE 749 with a dry weather flow of 121 m^3/day and a mean daily flow of 1139 m^3/day.

Table 4.1. Community Discharges in the vicinity of Loch Ewe

Scottish Water						SEPA					
Discharge Name	**Licence number**	**Location**	**Treatment Level**	**PE**	**Predicted Annual Spill Frequency**	**Discharge Name**	**Licence number**	**Location**	**Treatment Level**	**PE**	**DWF (m3/day)**
Loch Ewe East STW	CAR/L/1031729	NG 83690 92330	Sewage (Public) Primary	931		Loch Ewe East STW	CAR/L/1031729	NG 83690 92330	Sewage (Public) Primary	931	1512
Loch Ewe East STW, PS(1)	CAR/L/1031729	NG 87420 88520	CSO/EO		3	Loch Ewe East STW, PS(1)	CAR/L/1031729	NG 87420 88520	CSO/EO	-	-
Loch Ewe East STW, PS(2)	CAR/L/1031729	NG 87138 88937	CSO/EO		4	Loch Ewe East STW, PS(2)	CAR/L/1031729	NG 87138 88937	CSO/EO	-	-
Loch Ewe East STW, PS(3)	CAR/L/1031729	NG 86840 88910	CSO/EO		4	Loch Ewe East STW, PS(3)	CAR/L/1031729	NG 86840 88910	CSO/EO	-	-
Loch Ewe East STW, PS(4) EO	CAR/L/1031729	NG 86190 90130	CSO/EO		6	Loch Ewe East STW, PS(4) EO	CAR/L/1031729	NG 86190 90130	CSO/EO	-	-
Loch Ewe East STW, PS(5)	CAR/L/1031729	NG 85480 90450	CSO/EO		1	Loch Ewe East STW, PS(5)	CAR/L/1031729	NG 85480 90450	CSO/EO	-	-
Loch Ewe East STW, PS(6)	CAR/L/1031729	NG 85090 90710	CSO/EO		2	Loch Ewe East STW, PS(6)	CAR/L/1031729	NG 85090 90710	CSO/EO	-	-
Loch Ewe East STW, PS(7)	CAR/L/1031729	NG 84850 90800	CSO/EO		2	Loch Ewe East STW, PS(7)	CAR/L/1031729	NG 84850 90800	CSO/EO	-	-
Loch Ewe East STW, PS(8)	CAR/L/1031729	NG 84030 91440	CSO/EO		5	Loch Ewe East STW, PS(8)	CAR/L/1031729	NG 84030 91440	CSO/EO	-	-
						Pier Road Septic Tank	CAR/L/1001924	NG 8677 8906	Sewage (Public) Primary	-	-
Poolewe, STW	CAR/L/1040948	NG 85470 81250	Sewage (Public) Primary	749	-	Poolewe, STW	CAR/L/1040948	NG 85470 81250	Sewage (Public) Primary	749	1139
Poolewe, Hostel Pumping Station	CAR/L/1092167	NG 86021 81422	EO			Poolewe, Hostel Pumping Station	CAR/L/1092167	NG 86021 81422	EO	-	-

Scottish Water						SEPA					
Discharge Name	**Licence number**	**Location**	**Treatment Level**	**PE**	**Predicted Annual Spill Frequency**	**Discharge Name**	**Licence number**	**Location**	**Treatment Level**	**PE**	**DWF (m3/day)**
Riverside Pumping Station, Riverside Car Park	CAR/L/1092167	NG 8585 8085	EO			Riverside Pumping Station, Riverside Car Park	CAR/L/1092167	NG 8585 8085	EO	-	-
Poolewe Village Hall PS,	CAR/L/1092167	NG 85812 80781	EO			Poolewe Village Hall PS,	CAR/L/1092167	NG 85812 80781	EO	-	-
Poolewe, Bank Barn PS	CAR/L/1092167	NG 85800 81100	CSO		18	Poolewe, Bank Barn PS	CAR/L/1092167	NG 85800 81100	CSO	-	-

- = Data no provided DWF=Dry Weather Flow, EO=Emergency Overflow, MDF=Mean Daily Flow, NA=not applicable, PE=Population Equivalent, ST= Septic Tank, WWPS =Waste Water Pumping Station

4.2 Dispersion Studies

Scottish Water provided reports on the outcome of two dispersion studies undertaken in support of improvements to sewage discharges considered for the area.

A dispersion study for a possible location for the Loch Ewe East STW Outfall, was conducted by Anderson Marine Surveys Ltd. on behalf of Scottish Water Anderson Marine Surveys, 2007). The location conforms to the present discharge point. The studies were based on a combination of modelling and visual tracking of spot releases of dye. The report concluded that, while compliance with the regulatory target (100 faecal coliforms/100 ml, 89.6% of the time) would not necessarily be achieved at the shellfish waters boundary (see Section 12), it would be achieved at the licensed shellfish sites. The target concentration that was used would not necessarily ensure class A (Lee & Reese, 2014). However, the additional dilution that would occur between the identified compliance distance and the several fishery would mean that the impact from this source alone would be minimal.

A second dispersion study of the Poolewe STW discharge and two proposed discharges at Inverasdale and Cove was also conducted by Anderson Marine Surveys Ltd. on behalf of Scottish Water Anderson Marine Services, 2008). The study used a combination of bacterial spore and fluorescent microsphere tracers. Although some samples showed the presence of tracer to the east of the Isle of Ewe, predicted faecal coliform concentrations at the several fishery due to the studied discharge locations were of the order of 0.1 to 1.0 faecal coliforms/100 ml. Recorded faecal coliform concentrations off the northeastern side of the Isle of Ewe tended to be higher towards the southeastern end of the chanell than towards the northwestern end.

Neither study considered the impact of spills from CSOs or EOs.

4.3 Consented Private Discharges - SEPA

SEPA also provided information regarding consented private discharges within the request area. Discharges relating to abstraction, impoundment or engineering works have been excluded from assessment, as they should not contribute any faecal input to the area.SEPA provided information on 102 sewage discharge consents around Loch Ewe with PEs ranging from 5 to 50. The reported discharge locations are distributed on all sides on loch particularly on the northwestern side and around Aultbea and Mellon Charles on the northwestern side. The consented discharges are listed in Appendix 6 and the associated locations are shown in Figure 4.1 and 4.2. Fifty-nine of the 102 consents relate to discharges to soakaway. The effectiveness of soakaway systems depends on location and maintenance, and SEPA have identified previously that in remote areas, consents originally registered as discharging to land may be diverted to sea or watercourses upon failure of the soakaway fields. Of the remaining 43 consents, 19 were for discharges to watercourses flowing to Loch Ewe and 24 for discharges

directly to Loch Ewe or Loch Thurnaig. No consents were identified in relation to the Isle of Ewe.

Scottish Water describe a very large proportion of the community connected to the community sewage network around Mellon Charles and Aultbea. However a large number of private discharge consents relate to those areas. For the purpose of this assessment it has been assumed that the discharges to which these consents relate have not subsequently been connected to the community sewerage network.

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

Discharges within 2.5 km of the fishery area are given in Table 4.2.

Table 4.2 Private discharge consents within 2.5 km of the fishery

Licence Number	National Grid Reference	Discharge Type	Discharging to	PE
CAR/R/1014823	NG 84930 91470	Sewage (Private) Primary	Land	5
CAR/R/1016413	NG 87250 89030	Sewage (Private) Primary	Loch Ewe	5
CAR/R/1016414	NG 87248 89033	Sewage (Private) Primary	Loch Ewe	5
CAR/R/1017792	NG 87449 88968	Sewage (Private) Primary	Allt Beithe	15
CAR/R/1018221	NG 84106 90929	Sewage (Private) Primary	Loch Ewe	6
CAR/R/1018263	NG 85390 90650	Sewage (Private) Primary	Land	5
CAR/R/1018367	NG 87475 88942	Sewage (Private) Primary	Land	7
CAR/R/1020156	NG 84900 91670	Sewage (Private) Primary	Land	6
CAR/R/1021277	NG 85900 90450	Sewage (Private) Primary	Soakaway	5
CAR/R/1021628	NG 87180 89560	Sewage (Private) Primary	Soakaway	5
CAR/R/1027896	NG 87340 89819	Sewage (Private) Primary	Soakaway	5
CAR/R/1028405	NG 87150 89430	Sewage (Private) Primary	Soakaway	10
CAR/R/1030364	NG 86590 90330	Sewage (Private) Primary	Soakaway	6
CAR/R/1033898	NG 87441 88969	Sewage (Private) Primary	Allt Beithe	25
CAR/R/1045142	NG 85829 90634	Sewage (Private) Primary	Soakaway	5
CAR/R/1045219	NG 84715 91406	Sewage (Private) Primary	Soakaway	7
CAR/R/1045598	NG 87550 88940	Sewage (Private) Primary	Land	5
CAR/R/1046553	NG 84335 91117	Sewage (Private) Primary	Soakaway	6
CAR/R/1048260	NG 87416 88503	Sewage (Private) Primary	Loch Ewe	5
CAR/R/1048813	NG 84870 91110	Sewage (Private) Primary	Loch Ewe	5
CAR/R/1050074	NG 87800 88820	Sewage (Private) Primary	Soakaway	5
CAR/R/1050136	NG 87980 88810	Sewage (Private) Secondary	Land	5
CAR/R/1052477	NG 87100 89780	Sewage (Private) Primary	Land	6
CAR/R/1053531	NG 86910 89203	Sewage (Private) Primary	Loch Ewe	5
CAR/R/1055125	NG 85540 90840	Sewage (Private) Primary	Soakaway	5
CAR/R/1055814	NG 85905 90417	Sewage (Private) Primary	Soakaway	5
CAR/R/1058882	NG 87100 89724	Sewage (Private) Primary	UN/WC	5
CAR/R/1059001	NG 86330 90340	Sewage (Private) Primary	Land	6
CAR/R/1065648	NG 87897 88939	Sewage (Private) Primary	Allt Beithe	5
CAR/R/1065678	NG 85307 91083	Sewage (Private) Primary	Loch Ewe	5
CAR/R/1065855	NG 85420 90600	Sewage (Private) Primary	Soakaway	5
CAR/R/1067240	NG 87130 89386	Sewage (Private) Primary	Soakaway	5
CAR/R/1067968	NG 86960 89190	Sewage (Private) Primary	Loch Ewe	5
CAR/R/1068061	NG 87383 88496	Sewage (Private) Primary	Loch Ewe	5
CAR/R/1069077	NG 87474 88974	Sewage (Private) Primary	Allt Beithe	5
CAR/R/1069340	NG 84380 90980	Sewage (Private) Primary	Loch Ewe	5

Licence Number	National Grid Reference	Discharge Type	Discharging to	PE
CAR/R/1071435	NG 86968 89185	Sewage (Private) Primary	Loch Ewe	5
CAR/R/1071857	NG 84502 91696	Sewage (Private) Primary	Soakaway	5
CAR/R/1075916	NG 84690 91025	Sewage (Private) Primary	Soakaway	7
CAR/R/1076014	NG 84034 91373	Sewage (Private) Primary	Loch Ewe	0
CAR/R/1076051	NG 87137 89146	Sewage (Private) Primary	Loch Ewe	15
CAR/R/1076171	NG 84769 90926	Sewage (Private) Primary	Soakaway	6
CAR/R/1076177	NG 84160 91420	Sewage (Private) Primary	Camas nan Dornag	5
CAR/R/1076182	NG 84715 91165	Sewage (Private) Primary	Allt na Faiche	5
CAR/R/1076342	NG 85449 90943	Sewage (Private) Primary	Soakaway	5
CAR/R/1076572	NG 85428 90554	Sewage (Private) Primary	Loch Ewe	15
CAR/R/1077440	NG 84500 91340	Sewage (Private) Primary	Soakaway	5
CAR/R/1077442	NG 84460 91384	Sewage (Private) Primary	Soakaway	5
CAR/R/1077444	NG 84443 91331	Sewage (Private) Primary	Soakaway	5
CAR/R/1077553	NG 84668 91871	Sewage (Private) Primary	Land	5
CAR/R/1078375	NG 84421 91420	Sewage (Private) Primary	Soakaway	5
CAR/R/1080766	NG 85030 91350	Sewage (Private) Primary	Soakaway	5
CAR/R/1014823	NG 84930 91470	Sewage (Private) Primary	Land	5
CAR/R/1016413	NG 87250 89030	Sewage (Private) Primary	Loch Ewe	5
CAR/R/1016414	NG 87248 89033	Sewage (Private) Primary	Loch Ewe	5
CAR/R/1017792	NG 87449 88968	Sewage (Private) Primary	Allt Beithe	15
CAR/R/1018221	NG 84106 90929	Sewage (Private) Primary	Loch Ewe	6
CAR/R/1018263	NG 85390 90650	Sewage (Private) Primary	Land	5
CAR/R/1018367	NG 87475 88942	Sewage (Private) Primary	Land	7
CAR/R/1020156	NG 84900 91670	Sewage (Private) Primary	Land	6
CAR/R/1021277	NG 85900 90450	Sewage (Private) Primary	Soakaway	5

PE=Population Equivalent

SEPA provided information regarding four marine cage fish farms (MCFF) or shore bases within the area requested. Working facilities on these may have toilets, but no information was provided regarding these.

SEPA also provided information on one consent for water treatment filter backwash. This is likely to have a high bacterial content but be relatively small in volume. This coupled with the distance from the fishery (>6 km) means this is likely to have little impact on the fishery.

4.4 Shoreline Survey Discharge Observations

During the shoreline survey, 15 observations were noted of sewage discharges and/or sewage-related infrastructure. These are shown in Table 4.3.

Observation 1 reports a possible pumping station structure on the shore at Poolewe. This appears to be linked to the FE outfall for CAR/L/1040948. No pumping station EO has been reported for this location.

Observations 3 through 6 all plot within 50 m of each other. Observations 3, 4 and 5 relate to a Scottish Water pumping station (PS1) and a seawater sample taken in the vicinity. The seawater sample returned a value of 100 which does not show marked faecal contamination at the time of sampling.

Observation 8, 9, 10 and 11 report pipes along the shore with none reported as discharging. These may represent old private sewage discharges which no longer discharge, having been connected to the community sewage network.

Observation 12 is thought most likely to relate to PS5 of CAR/L/1031729.

Observation 14 is likely to be associated with CAR/R/1069340, a septic tank serving the marine research centre, which plots on the mean high water adjacent to this observation. It is consented for a PE of 5 but given that the centre is disused is unlikely to still be discharging.

Table 4.3 Discharge-associated observations made during the shoreline survey

No.	Date	NGR	Associated Photograph (Appendix 5)	Associated Sample	Description
1	04/11/2014	NG 85458 81063			Possible Poolewe pumping station structure on shore.
2	04/11/2014	NG 85658 80988			Poolewe hotel. Concrete slab with manhole covers on shore below.
3	04/11/2014	NG 87438 88516	Figure 5	100	Planned seawater sample below Scottish Water Community structure.
4	04/11/2014	NG 87453 88504			Metal pipe just visible in ground. Cannot see if flowing or not.
5	04/11/2014	NG 87485 88530			Scottish Water Structure on shore with houses behind.
6	04/11/2014	NG 87449 88560	Figure 6	<1000	Freshwater sample taken from pipe on shore. No flow measured as pipe only dripping. Houses behind.
7	04/11/2014	NG 87357 88981	Figure 7	110	Public toilets next to river
8	05/11/2014	NG 87213 89052			Plastic pipe, no flow.
9	05/11/2014	NG 87202 89059	Figure 15		Metal pipe, no flow.
10	05/11/2014	NG 87118 89112			Metal pipe, no flow. Houses behind.
11	04/11/2014	NG 86483 89819			Metal pipe leading onto shore. No flow. House behind.
12	04/11/2014	NG 85457 90566			Scottish Water Community structure.
13	04/11/2014	NG 84403 91080	Figure 11		Three large pipes leading into sea from disused marine research centre.
14	04/11/2014	NG 84485 91067			Broken clay pipe, flowing. Not sampled as only disused campsite on shore above.

4.5 Summary

A large proportion of the community surrounding the fishery is connected to one of the two community sewage networks. The continuous outfalls from these networks have been the subject of dispersion studies which anticipate minimal impact at the fishery. Intermittent discharges from CSOs (and potentially EOs) will input more concentrated sewage to the area between the mainland and the Isle of Ewe. Discharges from private septic tanks located on the mainland will add to background levels near to the eastern shore. No information was provided on any septic tanks associated with houses on the eastern side of the Isle of Ewe. These must have arrangements for the disposal of septic waste. If there are septic tanks which discharge to the marine or freshwater environments

they will have a direct impact at the fishery. The potential impact of any discharging to soakaway would depend on the effectiveness of that structure.

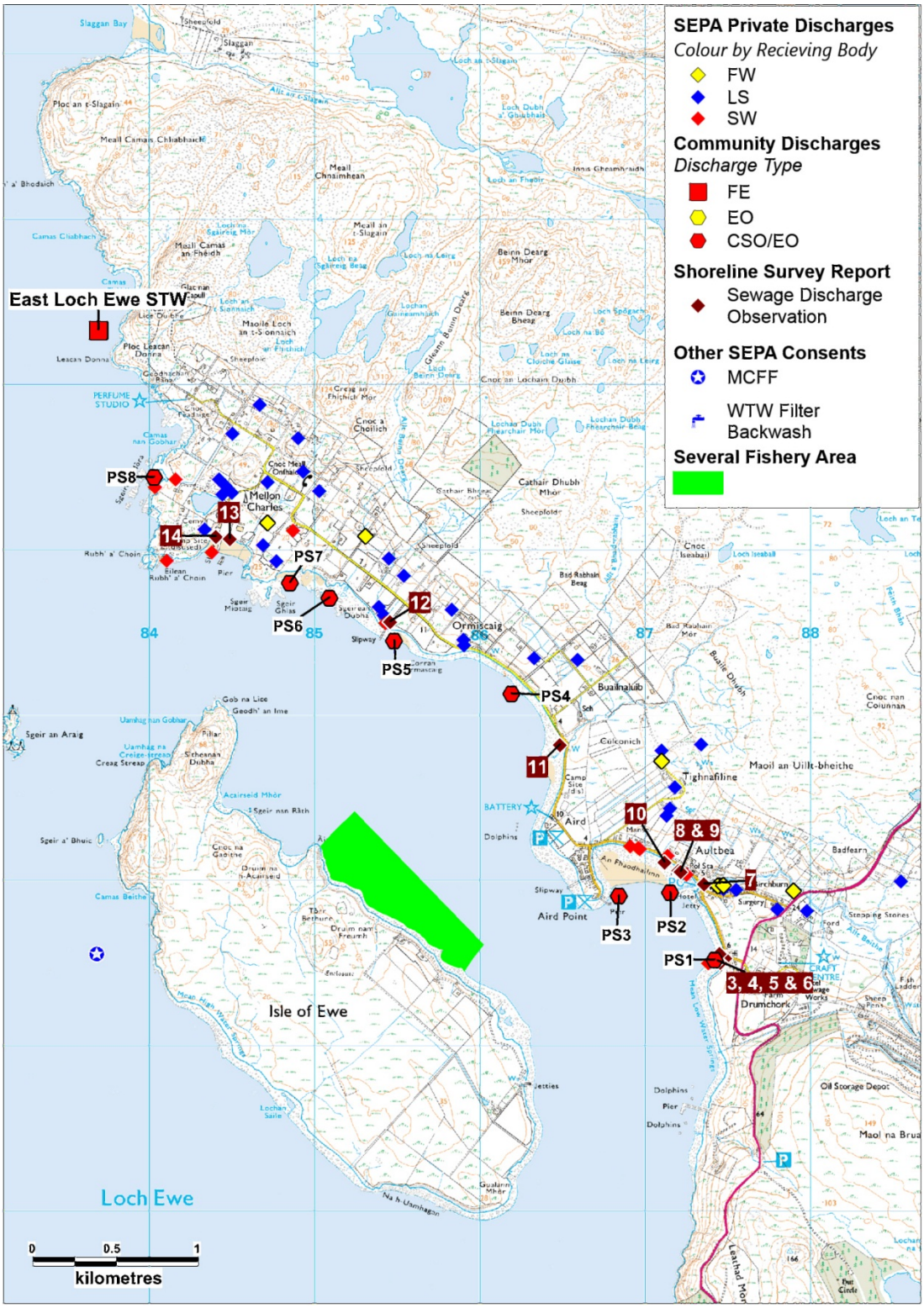


Figure 4.1 Map of discharges for Loch Ewe

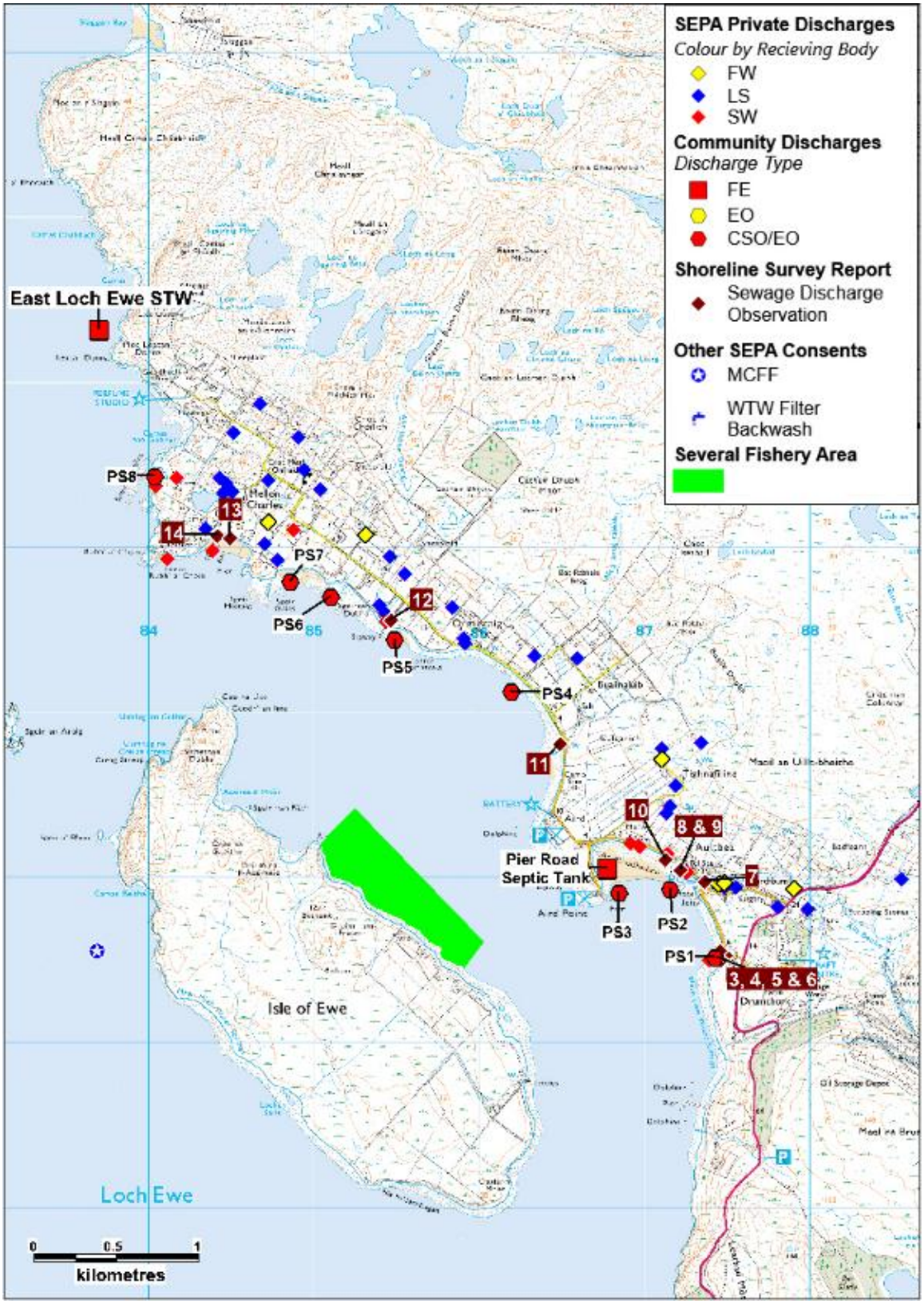


Figure 4.2 Map of discharges for East Loch Ewe

5. Agriculture

Information on the spatial distribution of animals on land adjacent to or near the several fishery can provide an indication of the potential amount of organic pollution from livestock entering the shellfish farm area. Agricultural census data to parish level was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for the Gairloch parish. Reported livestock populations for the parish in 2013 is listed in Table 5.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reporting would have made it possible to discern individual farm data. Any entries which relate to fewer than five holdings, or where two or fewer holdings account for 85% or more of the information, are replaced with an asterisk.

Table 5.1 Livestock numbers in the Gairloch agricultural parish

	Gairloch	
	876 km^2	
	Holdings	Numbers
Pigs	14	42
Poultry	46	754
Cattle	45	822
Sheep	102	13502
Horses used in Agriculture	*	*
Other horses and ponies	16	46

* data withheld

The livestock census numbers for Gairloch relate to a very large area (approximately 876 km^2) and it is therefore not possible to determine the spatial distribution of the livestock on the shoreline adjacent to the survey area or to identify how many animals are likely to impact the catchment around the shellfish farm. Although the figures are of little use in assessing the potential impact of livestock contamination to the shellfishery they do give an idea of the total numbers of livestock over the broader area. Sheep were kept in moderate numbers and pigs, poultry and cattle were keep in small numbers. Horses used agriculture were not reported due to the small number of holdings.

A source of spatially relevant information on livestock population in the area was the shoreline survey (see Appendix 5) which only relates to the time of the site visit on the 3rd – 5th November 2014. Observations made during the survey are dependent upon the viewpoint of the observer some animals may have been obscured by the terrain.

Approximately 18 sheep and one horse were observed on the eastern mainland shoreline during the shoreline survey. A farmhouse and barn were observed on the island of Ewe, however it was not confirmed as a working farm and no livestock were observed.

The 1:25,000 Ordnance Survey map identified a farm, cattle grid and sheep wash inland of the southern end of the loch. Further sheep pens and sheepfolds were identified along the eastern and western coastline of the loch. SEPA identified a sheep dip on to land on the northeast coastline of the loch as shown in Figure 5.1. Aerial imagery (http://www.bing.com/maps) showed that some of the fields on the southwestern side of the Isle of Ewe appeared to be used for some type of farming but the specific use was not evident and no livestock were visible in the images).

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

Numbers of sheep are expected to be approximately double during the spring and summer months when lambs are present. Any contributions of faecal contamination from livestock are expected to be low, with livestock grazing on the mainland adjacent to the east of several fishery having a minor impact on the eastern stretch of the fishery. If the island is used for farming/grazing, then this will impact more directly on the western side of the fishery.

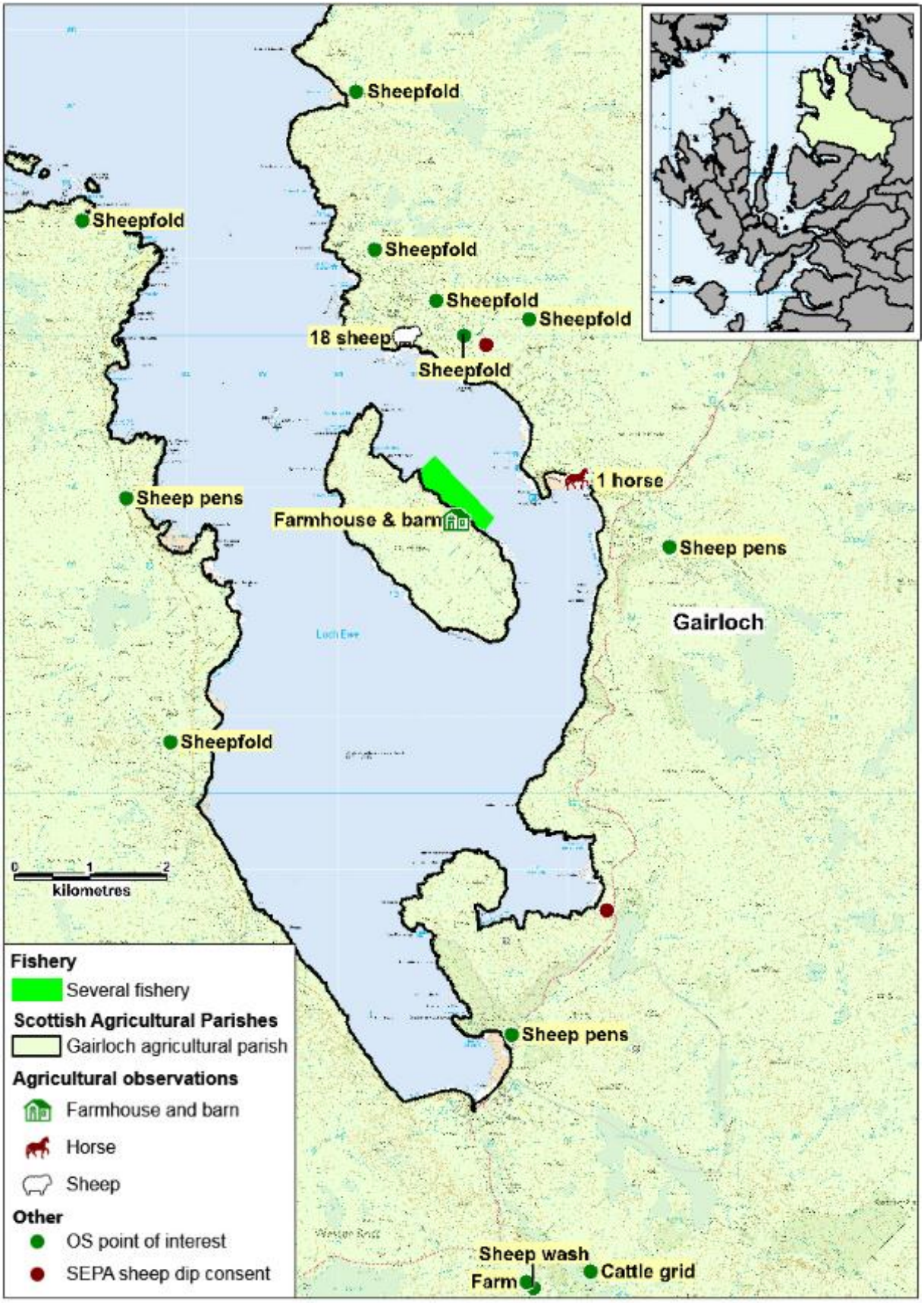


Figure 5.1 Livestock observations at Loch Ewe and Loch Thurnaig

6. Wildlife

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

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

Pinnipeds

The Special Committee on Seals report (SCOS, 2013) identifed that seals may be present in the area around Loch Ewe, based on surveys undertaken during August between 2007 and 2011. The report also noted that common seal populations along the west coast of Scotland remained unchanged between 2000 and 2010. Population estimates were not available for grey seal populations. Anecdotal accounts indicate that common seals are resident within Loch Ewe, whilst grey seals are more commonly found at the entrance to the loch (Visit Loch Ewe, 2015)(Poolewe B&B, 2012).

No seals were observed during the shoreline survey.

Cetaceans

Over the past six years, there have been sightings of common dolphins and bottlenose dolphins within Loch Ewe (Hebridean Whale and Dolphin Trust, 2015). There are also anecdotal accounts of other cetaceans such as porpoise and whales in the waters outside of Loch Ewe (Visit Loch Ewe, 2015). No cetaceans were observed during the shoreline survey.

Seabirds

Seabird data was downloaded from the collated JNCC dataset from the website (JNCC, 2014) in March 2014. The dataset was then manipulated to show the most recent data where repetitions of counts were present. It should be appreciated that the sources of this data are varied, with some recorded as unknown or estimated, whilst some come from reliable detailed surveys such as those carried out for the Seabird 2000 report by Mitchell *et al.*, (2004). Data applicable for the 5 km area around the several fishery area are listed in Table 6.1.

Table 6.1 Seabird counts within 5 km of the Loch Ewe several fishery area

Common name	Species name	Count*	Method	Accuracy
Shag	*Phalacrocorax aristotelis*	120	Occupied nests	Accurate
Herring Gull	*Larus argentatus*	124	Occupied nests	Accurate
Common Gull	*Larus canus*	14	Occupied nests	Accurate
Lesser Black-Backed Gull	*Larus fuscus*	12	Occupied nests	Accurate
Great Black-Backed Gull	*Larus marinus*	14	Occupied nests	Accurate
Fulmar	*Fulmarus glacialis*	166	Occupied sites	Accurate
Black Guillemot	*Cepphus grylle*	59	Individuals on land	Accurate

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

The JNCC seabird data indicated that the area supports large breeding colonies of shags, herring gulls and fulmars. Larger breeding colonies were situated on the northwestern side of the Isle of Ewe and also at the northwestern end of Loch Ewe on the islands of Eilean Furadh Mor and Eilean Furadh Beag. The actual impact of these birds on the water quality in the vicinity of the fishery would depend on the area over which the travel for food. No sightings were recorded in the immediate area around the several fishery area.

Birds were the only wildlife observed during the shoreline survey. Species included cormorants, herons, mallard ducks, greylag geese, lesser black-backed gulls, common gulls which were the most frequently observed and were noted by the fishery area, and unidentified gulls. Starlings and hooded crows were also noted.

Otters

There are reports of the Eurasian otter (*Lutra lutra*) around Loch Ewe in the data from the National Biodiversity Network (https://data.nbn.org.uk). Anecdotal accounts also suggest otters can be regularly seen in Loch Ewe (Walkhighlands, 2013). Furthermore there is also a Special Area of Conservation south of Loch Ewe in Loch Maree, which has otters in its designation annex 1 (JNCC, 2015). No otters were observed during the shoreline survey.

Deer

There are no accurate records of deer populations in the area. The National Biodiversity Network reported several records of red deer around the shores of Loch Thurnaig (https://data.nbn.org.uk). There are also anecdotal accounts of red deer in the Loch Ewe area (Visit Loch Ewe, 2015). Deer are expected to move down to lower wooded areas during the colder winter months from higher areas.

Conclusion

Seabirds are expected to be the main wildlife contributors to background levels of contamination at the Loch Ewe king scallop fishery. Intermittent inputs from seals, cetaceans, otters and deer may also occur. There is no evidence on which to base an assessment of different impact across the several fishery area.

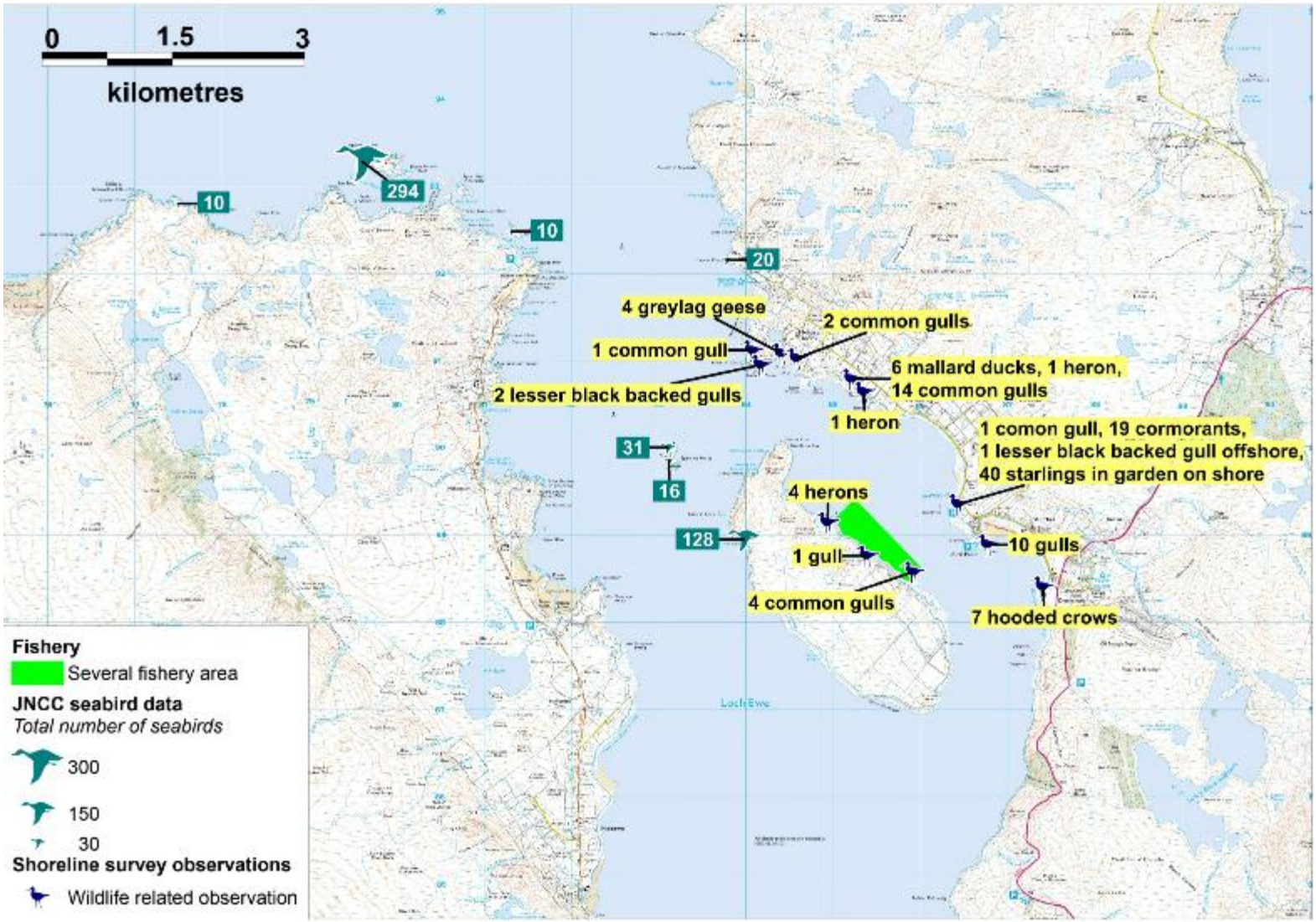


Figure 6.1 Map of wildlife distributions around Loch Ewe and Loch Thurnaig

7. Land Cover

The Land Cover Map 2007 data for the area is shown in Figure 7.1. The predominant land cover types in the vicinity of the several fishery area on the Isle of Ewe are dwarf shrub heath, bog, improved grassland and rough grassland. There are extensive areas of imp4roved grassland shown on the mainland as well as areas of broad leaved and coniferous woodland on the mainland. The settlements of Mellon Charles, Buailnaluib, Aird, Aultbea, Poolewe and Cove are represented as a built up/urban areas.

Faecal indicator organism export coefficients for faecal coliform bacteria have been found to be approximately 1.2 – 2.8x10^{9} cfu km^{-2} hr^{-1} for urban catchment areas, approximately 8.3x10^{8} cfu km^{-2} hr^{-1} for areas of improved grassland and approximately 2.5x10^{8} cfu km^{-2} hr^{-1} 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 several fishery is from the areas of improved grassland and rough grazing located south of the fishery. Any impact is likely to be greatest at the southeastern end of the fishery. This contribution would be expected to increase after rainfall events.

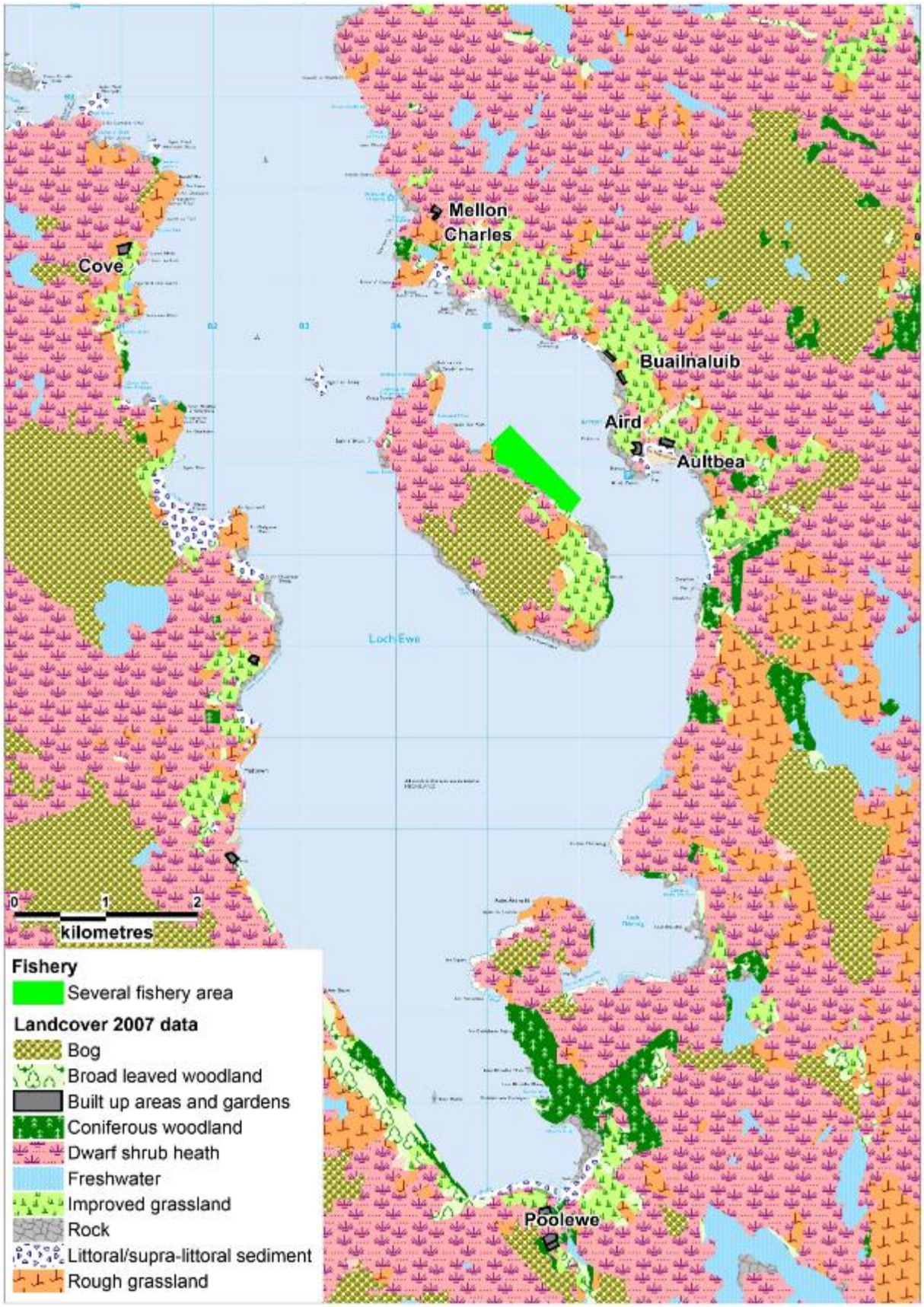
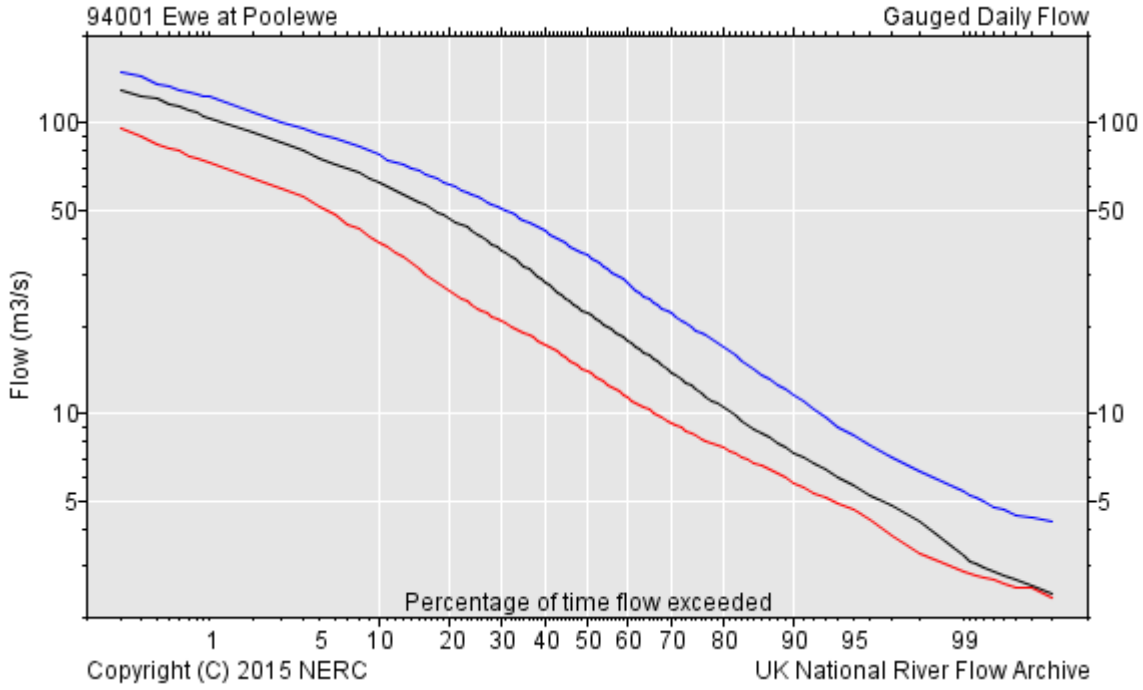


Figure 7.1 LCM2007 land cover data for the area around Loch Ewe & Loch Thurnaig

8. Watercourses

The Ewe, Poolewe gauging station is located on the River Ewe approximately 800 m upstream from the mouth of the river. Flow data is provided for the period 1970-2013, with mean measured flow at 29.586 m^3/s and a base flow index of 0.64 m^3/s (National River Flow Archive, 2015:
http://www.ceh.ac.uk/data/nrfa/data/meanflow.html?94001). The flow duration curve is displayed in Figure 8.1. The x-axis graph shows the percentage of time for which the flows on the left-hand y-axis are exceeded. The Q50 value, the flow which is exceeded for 50% of the time, on an annual basis, is given as 22.17 m^3/s (this corresponds to approximately 1920000 m^3/d). The flows are markedly higher in winter (blue line) than in summer (red line).



Key: **Black line - annual; blue line - December to March; red line - June to September.**

Figure 8.1 Flow duration curve for Ewe, Poolewe Courtesy of UK NRFA, 2015

Spot measurements of flow and microbial content were obtained during the shoreline survey conducted on the 3rd - 5th November 2014. Heavy precipitation occurred in the 48hrs prior to the survey. The watercourses listed in Table 8.1 are those recorded during the shoreline survey. Nine watercourses and one area of land drainage were observed and locations and loadings are mapped in Figure 8.1.

Table 8.1 Watercourses entering Loch Ewe and Loch Thurnaig

No.	Eastings	Northings	Description	Width (m)	Depth (m)	Flow (m^3/d)	Loading (*E. coli* per day)
1	187788	888097	Allt na Faiche	1.22	0.21	16800	3.5×10^{10}
2	187471	888551	Unnamed watercourse	1.91	0.17	10400	9.4×10^{9}
3	187357	888981	Allt Bhruachan Ruadha	2.28	0.17	19500	4.5×10^{10}
4	186509	889801	Allt an Raoin Chiuaidh	6.62	0.15	48200	2.0×10^{11}
5	185344	890642	Allt Beithe	11.4	0.29	112000	1.2×10^{11}
6	185205	890788	Unnamed watercourse	0.88	0.24	6530	1.3×10^{9}
7	184578	891027	River Ewe	Not measured			
8	185806	880794	Unnamed watercourse	1.62	0.17	10100	4.0×10^{9}
9	185073	888959	Unnamed watercourse	0.28	0.14	467	$<4.7 \times 10^{7}$

The River Ewe, located in Poolewe is the largest watercourse entering the loch. A sample taken from the River Ewe during the shoreline survey yielded a result of <10 *E. coli* cfu/100 ml. Therefore, despite the very high flow expected from the National Rivers Archive data, the upper limit on the possible loading was $<1.9 \times 10^{11}$. Given the distance from the shellfishery, any impact from this source would be markedly lower than the watercourses located in the vicinity of the several area.

Eight other watercourses were measured and sampled during the shoreline survey. Two of the watercourses (no.8 and no.9), discharge directly into the several fishery area and moderate and low estimated *E. coli* loadings of 4.0×10^{9} and $<4.7 \times 10^{7}$ respectively. Six additional watercourses were observed along the mainland coastline opposite the Isle of Ewe. These had moderate to high estimated *E. coli* loadings from 1.3×10^{9} to 2.0×10^{11}.

Overall, freshwater inputs are expected to provide moderate levels of contamination to the several fishery, with the highest impact expected in the areas of the fishery closest to the watercourses on the Isle of Ewe.

Figure 8.2 Map of watercourse loadings at Loch Ewe & Loch Thurnaig

9. Meteorological Data

The nearest weather station for which a near complete rainfall data set was available is located at Aultbea No 2, situated on the eastern edge of the production area. Rainfall data was available for January 2008 – December 2013. The nearest wind station is Stornoway, located 60 km North West of the production area. Conditions will differ between this station and the fisheries due to the distances between them. However, this data is still shown as it can be useful in identifying seasonal variation in wind patterns.

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

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 *.

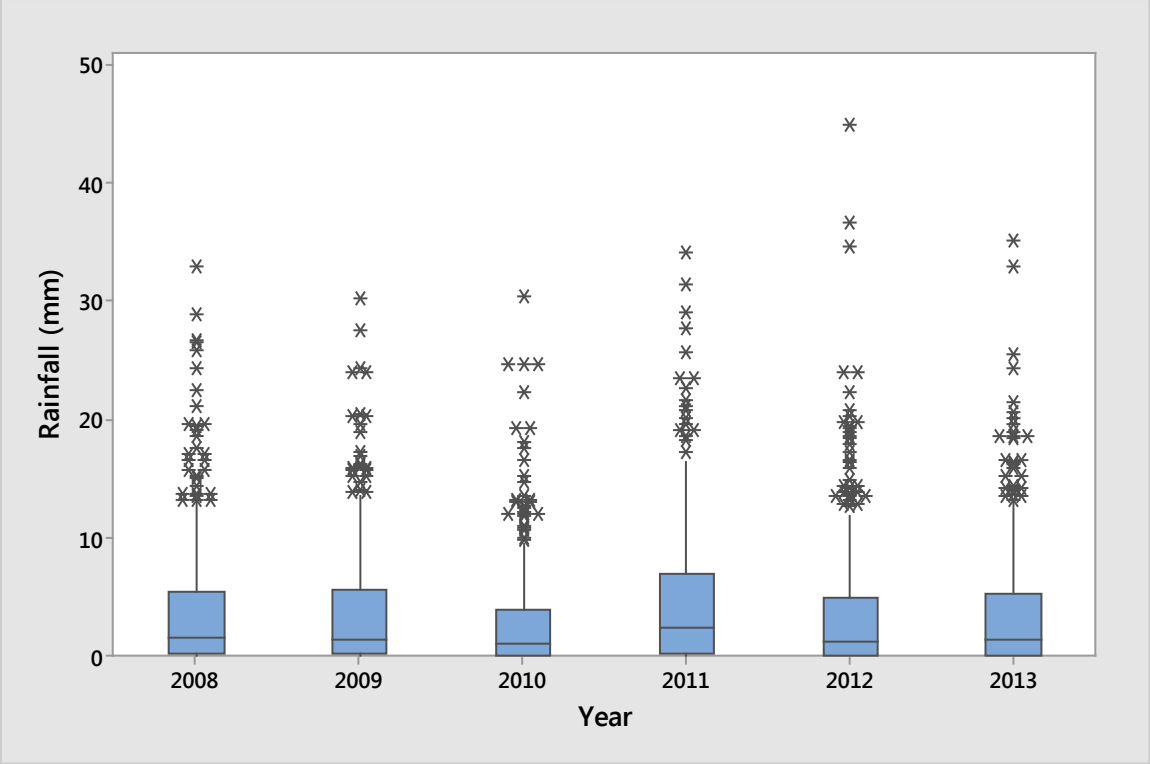


Figure 9.1 Box plot of daily rainfall values by year at Aultbea No 2 (2008 – 2013)

Total annual rainfall varied from year to year, with 2010 being the driest year (1037 mm) and 2011 the wettest (1695 mm). A rainfall event exceeding 40 mm/d occurred in 2012.

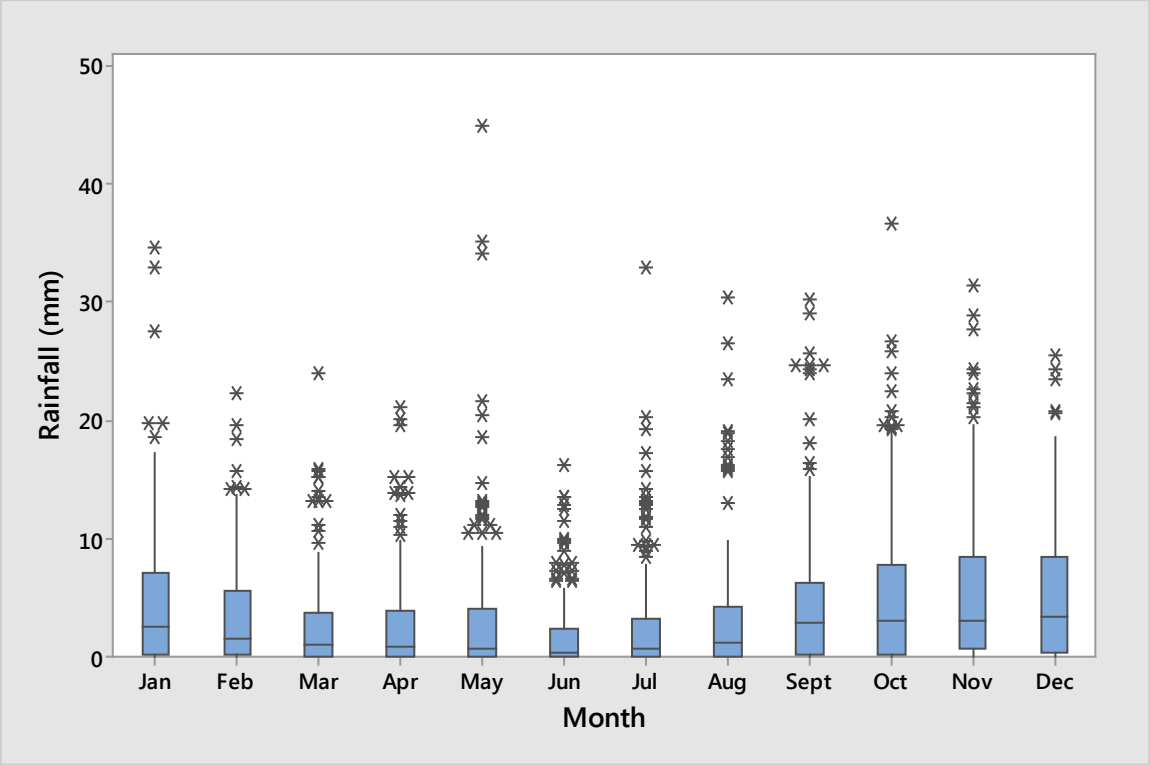


Figure 9.2 Box plot of daily rainfall values by month at Aultbea No 2 (2008 – 2013)

Monthly total values were higher during the autumn and winter. Rainfall was greatest in October (1025 mm) and least in June (351 mm). A rainfall event exceeding 40 mm/d occurred in May.

For the period considered here (2008 – 2013) 43 % of days received daily rainfall of less than 1 mm and 11 % of days received daily rainfall of over 10 mm.

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

9.2 Wind

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

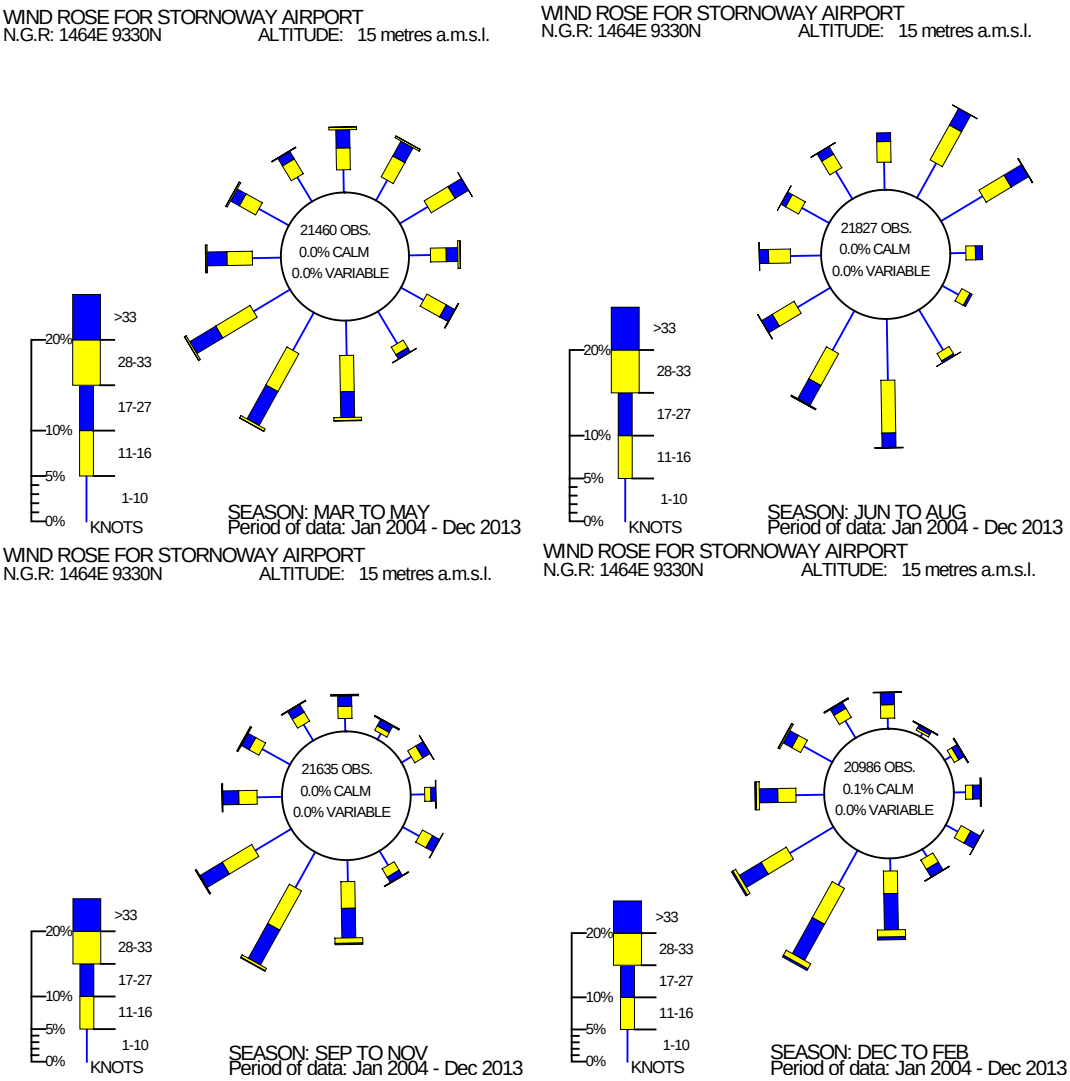


Figure 9.3 Seasonal wind roses for Stornoway

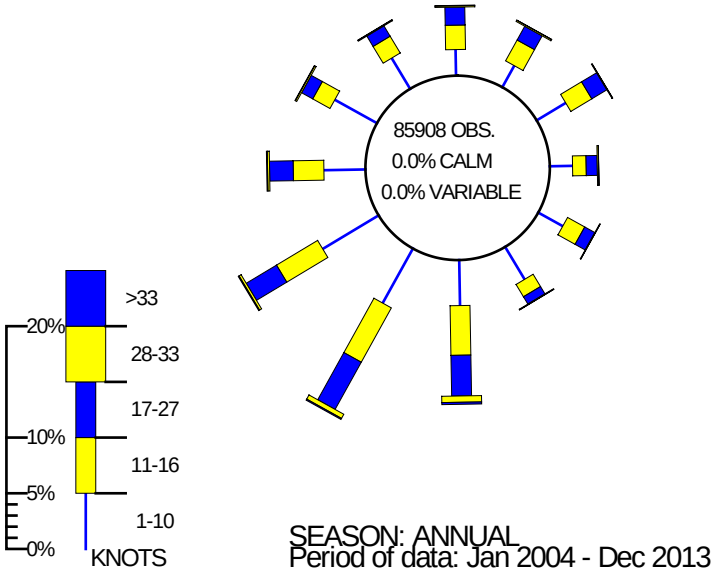


Figure 9.4 Annual wind rose for Stornoway

Overall, winds were predominantly from the southwest. However, during summer, southerly winds predominated and there were also relatively strong winds from the northeast. 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 Ewe and and Loch Thrunaig is classified for production of king scallops (Pecten maximus). It has been classified for production since 2003. The classification history since 2006 is listed in Table 10.1 below.

Table 10.1 Loch Ewe And Loch Thurnaig: (king scallop) 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	A	A	A	A	A
2010	A	A	A	A	A	A	A	A	A	A	A	A
2011	A	A	A	A	A	A	A	A	A	A	A	A
2012	A	A	A	A	A	A	A	A	A	A	A	A
2013	A	A	A	A	A	A	A	A	A	A	A	A
2014	A	A	A	A	A	A	A	A	A	A	A	A
2015	A	A	A									

The area has been consistently given a year-round A classification since April 2006.

The production area was also classified for the production of common mussels (Mytilus edulis) from 2003. Production continued until 2012 when the site was declassified. The classification history since 2006 is given in Table 10.2 below.

Table 10.2 Loch Ewe And Loch Thurnaig: (common mussel) classification history

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

Up until 2010, the mussels were given a year-round A classification. However, in that year, and 2011, they were given B classifications in October and November, with A classification the rest of the year.

11. Historical E. coli Data

11.1 Validation of historical data

Results for all samples assigned against Loch Ewe & Loch Thurnaig production area for the period 01/01/2009 to the 19/01/2015 were extracted from the FSAS database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. The data was extracted on 19/01/2015. All *E. coli* results were reported as most probable number (MPN) per 100 g of shellfish flesh and intravalvular fluid.

Fifty-one sample results reported as <20 or <18 were reassigned a value of 10 *E. coli* MPN/100 g and one common mussel sample with a result of >18000 was reassigned a value of 36000 *E. coli* MPN/100 g for the purposes of statistical evaluation and graphical representation.

Loch Ewe

One sample was stated as rejected and was omitted from the dataset. The remaining 70 sample results were received at the laboratory within 48 hours since collection, had box temperatures of ≤8^{o}C and plotted within 100 m of the production area.

Loch Thurnaig

One sample stated as rejected and two samples which did not have reported results were omitted from the dataset. One sample also lay >100 m outside the production area and was also omitted from the dataset. The remaining 27 samples were received at the laboratory within 48 hrs since collection, with box temperatures of <8^{o}C.

11.2 Summary of microbiological results

Summaries of samples and results from Loch Ewe and Loch Thurnaig fisheries are listed in Table 11.1.

Table 11.1 Summary of historical sampling and results

Sampling Summary		
Production area	Loch Ewe and Thurnaig	
Site	Loch Ewe	Loch Thurnaig
Species	King scallops	Common mussels
SIN	RC-142-250-07	RC-142-251-08
Location	Various	Various
Total no of samples	70	27
No. 2009	12	12
No. 2010	11	10
No. 2011	10	5
No. 2012	12	-
No. 2013	12	-
No. 2014	12	-
No. 2015	1	-
Results Summary		
Minimum	<18	<20
Maximum	490	>18000
Median	20	<20
Geometric mean	30	19
90 percentile	215	198
95 percentile	330	>18000
No. exceeding 230/100g	4 (6%)	2 (7%)
No. exceeding 1000/100g	0	1 (4%)
No. exceeding 4600/100g	0	1 (4%)
No. exceeding 18000/100g	0	1 (4%)

Results at both sites were low, with more than 90% being less than 230 *E. coli* MPN/100 g. However, a single very high result was seen in the limited number of results from Loch Thurnaig whereas the greater number of results for the scallop several area yielded a maximum result of 490 *E. coli* MPN/100 g.

The mussel results for Loch Thurnaig have not been considered further in this analysis as this species has not been sampled recently for *E. coli* testing, are at a separate location, and would be expected to show different levels from scallops in parallel sampling (Lee & Silk, 2013).

11.3 Overall geographical pattern of results

The geographical locations of samples assigned to the Loch Ewe King scallops site are shown in Figure 11.1 with the symbols graduated proportional to the magnitude of the *E. coli* result.

Eight of the samples had no recorded sampling locations and therefore could not be included in the geographical analysis. Suspected typographical errors in the recorded locations of two samples (two digits switched round) were corrected to allow for inclusion in the geographical analysis.

The majority of Loch Ewe scallop samples were recorded as having been taken within, or in close proximity to, the several fishery area, located on the northeastern side of the Isle of Ewe: most from a single NGR recorded to 100 m accuracy (NG 857 888). This included samples taken in 2014 and 2015. Five samples were reported against NG 852 891, also to 100 m accuracy. Apart from three, other samples were reported against other individual locations around, or in the vicinity of, the several fishery. These other three were reported as having been taken elsewhere around the loch (these locations are not shown in Figure 11.1).

Given that a large proportion of the samples had been assigned to a small number of locations reported to 100 m accuracy, it was not possible to undertake an assessment of spatial variation of the results with respect to sampling location.

Figure 11.1 Map of reported sampling locations at Loch Ewe & Loch Thurnaig

11.4 Overall temporal pattern of results

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

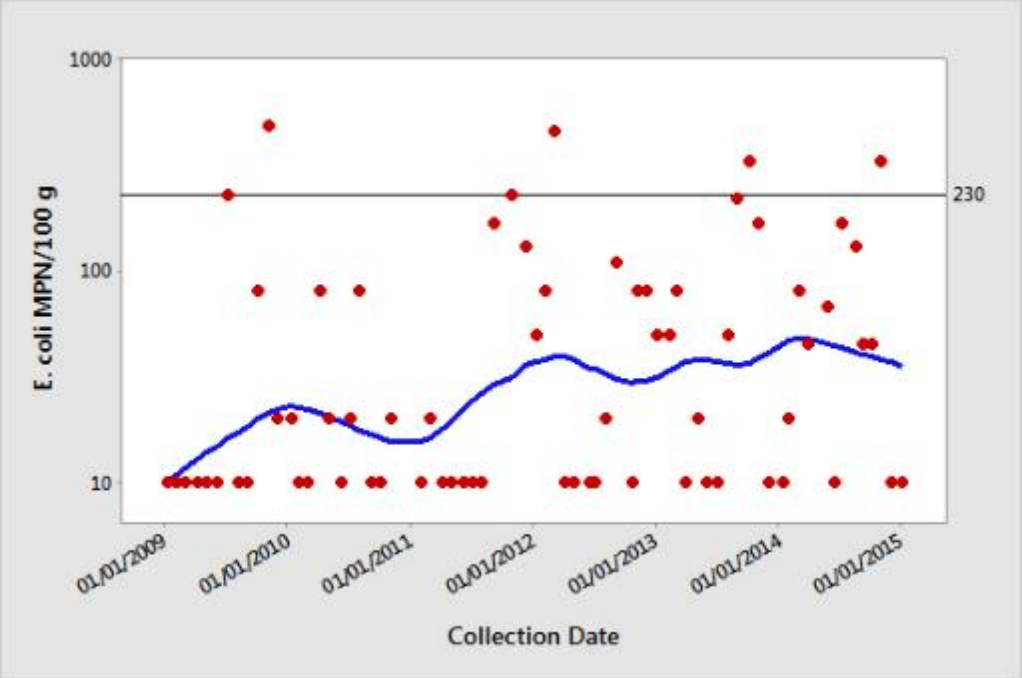


Figure 11.2 Scatterplot of *E. coli* results by collection date in results from Loch Ewe scallops

Contamination levels show a gradual increase across the sampling period, as highlighted by the trend line. This is largely due to a decrease in the proportion of <20 *E. coli* MPN/100 g sample results and not an increase in the proportion or magnitude of high results..

11.5 Seasonal pattern of results

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

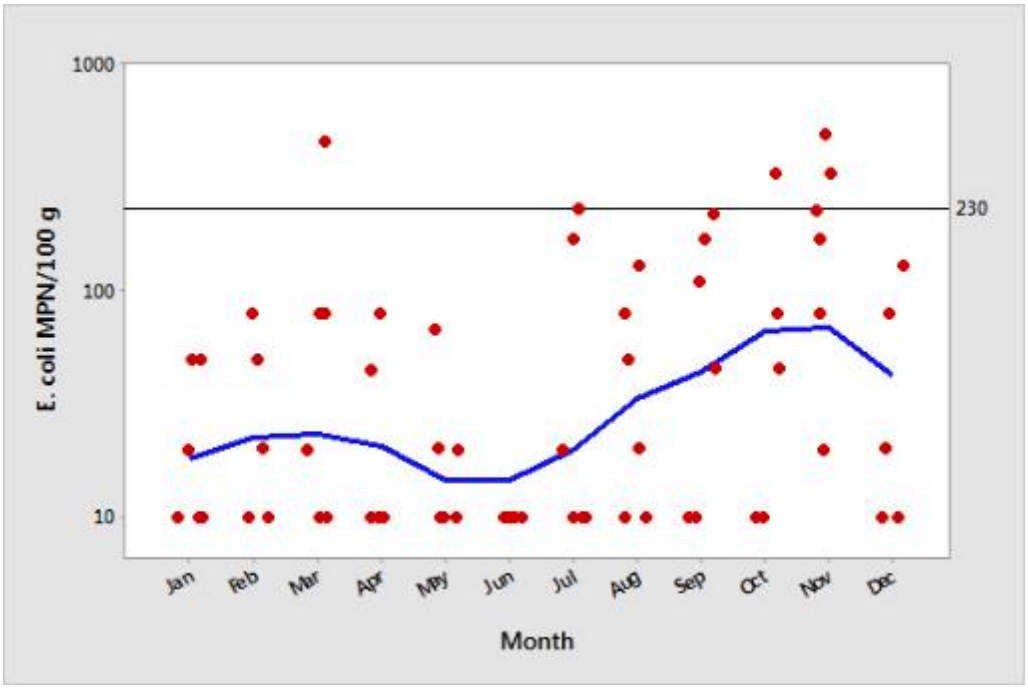


Figure 11.3 Scatterplot of *E. coli* results by month at Loch Ewe, fitted with a lowess line

Contamination levels are shown to increase between June and November, as highlighted by the lowess line. Samples with results >230 *E. coli* MPN/100 g were taken in March, October and November.

For statistical evaluation, seasons were split into spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). A boxplot of *E. coli* results by season for Loch Ewe king scallops is presented in Figure 11.5.

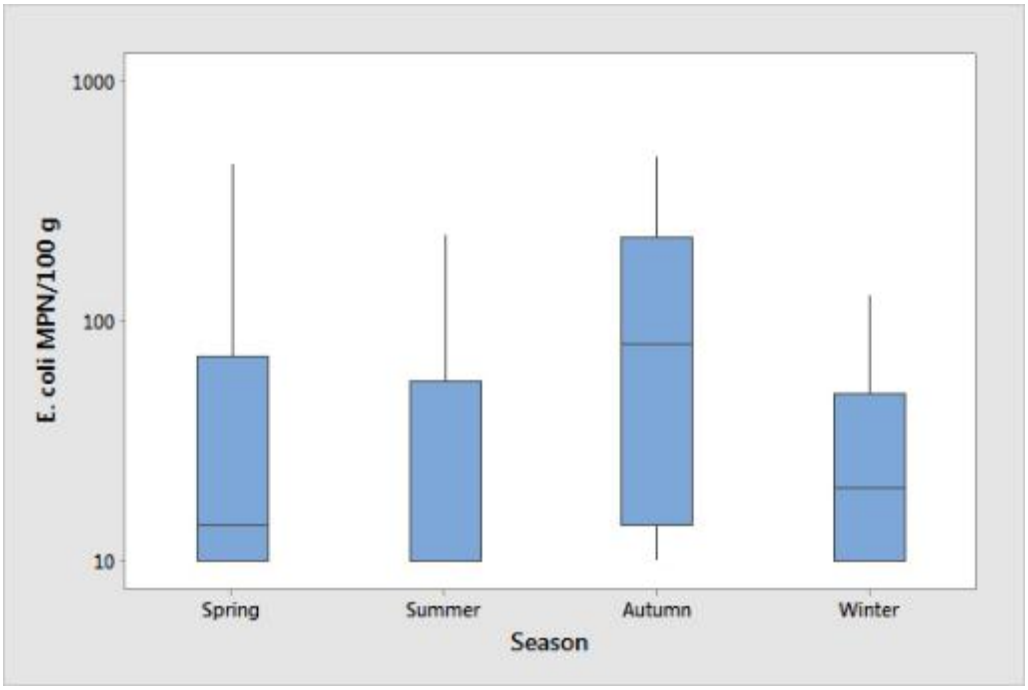


Figure 11.4 Boxplot of *E. coli* results by season at Loch Ewe

A highly significant difference was found between *E. coli* results for Loch Ewe king scallops by season (one-way ANOVA, p = 0.009) (Appendix 4). Results from samples taken in the autumn were significantly higher than those from samples taken in spring, summer and winter.

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 Aultea No. 2, which lies on the eastern edge of the Loch Ewe & Loch Thurnaig production area. Rainfall data was purchased from the Meteorological Office for the period of 01/01/08 - 31/12/2013 (total daily rainfall in mm). Data was extracted from this for 57 of the sample results at the Loch Ewe King scallops site between 01/01/2009 - 31/12/2014.

Two-day rainfall

A scatterplot of *E. coli* results against total rainfall recorded on the two days prior to sampling for Loch Ewe is displayed in Figure 11.6. Jittering was applied to points at 0.02 (x-axis) and 0.001 (y-axis) respectively.

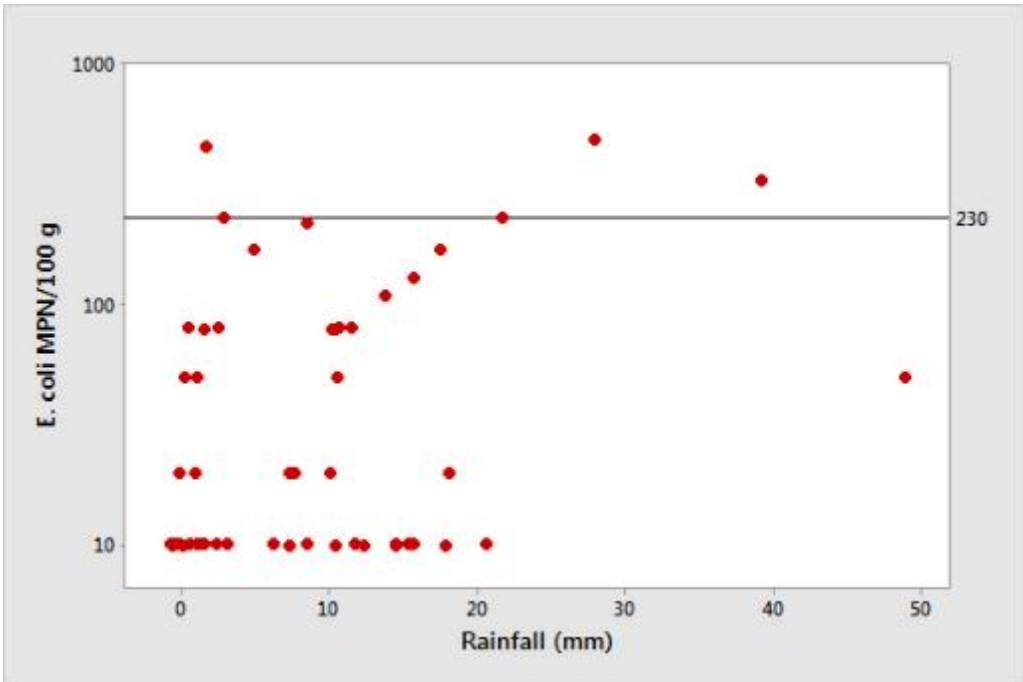


Figure 11.5 Scatterplot of *E. coli* results against rainfall in the previous two days at Loch Ewe

A significant correlation was found between *E. coli* results and the previous two day rainfall (Spearman's rank correlation r = 0.327, p = 0.013). More than half of the results of <20 *E. coli* MPN/100 g were associated with samples taken at rainfall levels of <5 mm over the previous two days.

Seven-day rainfall

The effects of heavy rainfall may take differing amounts of time to be reflected in shellfish sample results in different system, the relationship between rainfall in the previous seven days and sample results was investigated in an identical manner to the above. A scatterplot of *E. coli* results against total rainfall recorded for the seven days prior to sampling at Loch Ewe is shown in Figure 11.7. Jittering was applied to points at 0.02 (x-axis) and 0.001 (y-axis) respectively.

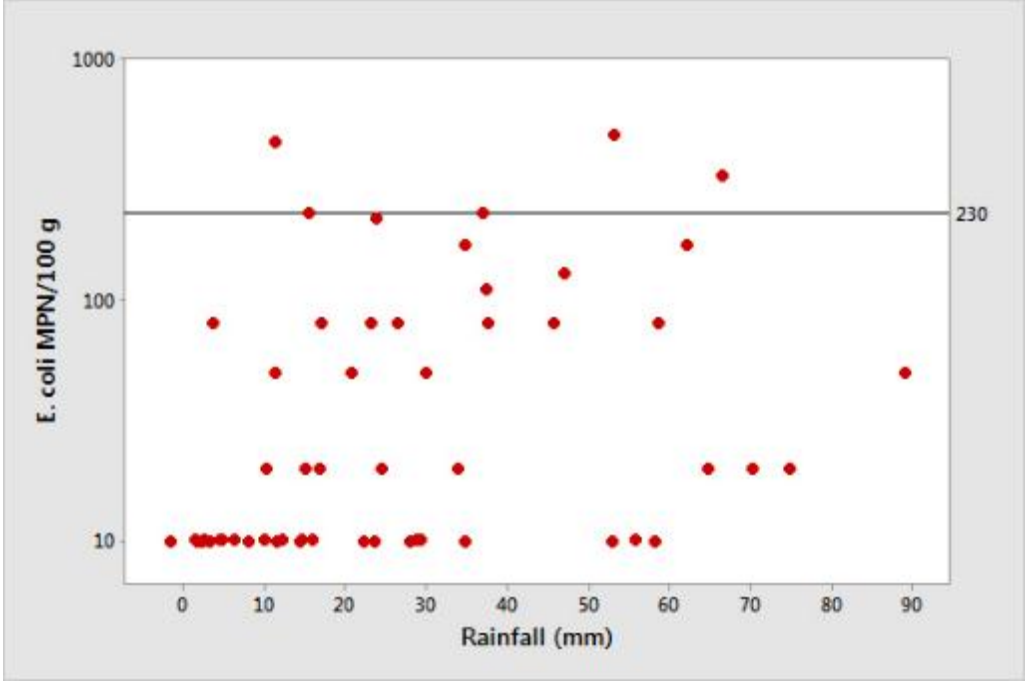


Figure 11.6 Scatterplot of *E. coli* results against rainfall in the previous seven days at Loch Ewe

A highly significant correlation was found between *E. coli* results and the previous seven day rainfall (Spearman's rank correlation r = 0.427, p = 0.001). A large proportion of results of <20 *E. coli* MPN/100 g were from samples taken at <20 mm previous seven day rainfall.

11.6.2 Analysis of results by tidal height

Spring/neap tidal cycle

Spring tides are large tides that occur fortnightly and are influenced by the state of the lunar cycle. They reach above the mean high water mark and therefore increase circulation and particle transport distances from potential contamination sources on

the shoreline. The largest (spring) tides occur approximately two days after the full/new moon, at about 45º on a polar plot. The tides then decrease to the smallest (neap) tides, at about 225º, before increasing back to spring tides. A polar plot of *E. coli* results against the lunar cycle is shown for Loch Ewe in Figure 11.8. It should be noted local meteorological conditions (e.g. wind strength and direction) can also influence tide height, but are not taken into account in this section.

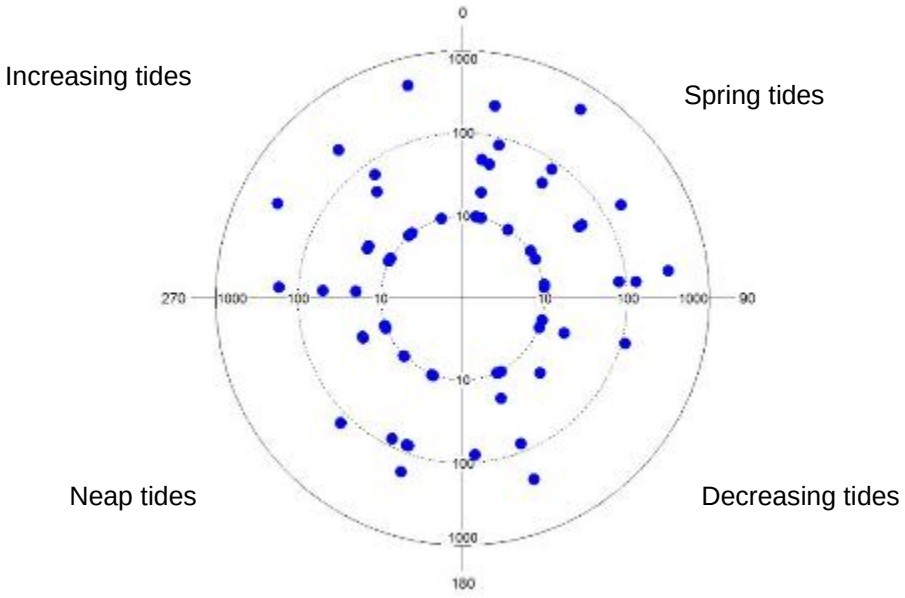


Figure 11.7 Polar plots of E. coli results on the spring/neap tidal cycle at Loch Ewe

No significant correlation was found between $\log_{10}$ *E. coli* results and the spring/neap tidal cycle (circular-linear correlation r = 0.162, p = 0.174).

High/low tidal cycle

Tidal state (high/low tide) changes the direction and strength of water flow around production areas. Depending on the location of contamination sources, tidal state may cause marked changes in water quality near the vicinity of the farms. Shellfish species response time to *E. coli* levels can vary from within an hour to a few hours. A polar plot of *E. coli* results against the high/low tidal cycle for Loch Ewe is shown in Figure 11.9. High water is located at 0º on the polar plot and low water at 180º.

High and low water data from Mellon Charles was extracted from POLTIPS-3 in January 2015. This site lies within the northeast extent of the production area and it is assumed that the tidal state will be similar between sites.

No significant correlation was found between $\log_{10}$ *E. coli* results and the high/low tidal cycle (circular-linear correlation r = 0.148, p = 0.23). The majority of samples were taken over the last half of ebb tide.

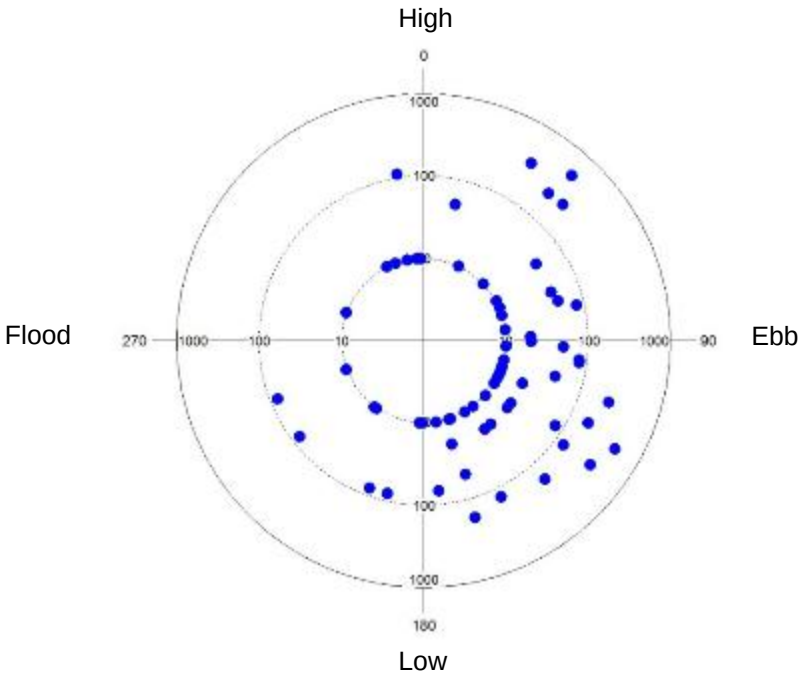


Figure 11.8 Polar plots of E. coli results on the high/low tidal cycle at Loch Ewe

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 *E. coli* results against water temperature for Loch Ewe is shown in Figure 11.10. Water temperature was recorded for 67 out of the 70 samples. Jittering was applied to points at 0.02 (x-axis) and 0.001 (y-axis) respectively.

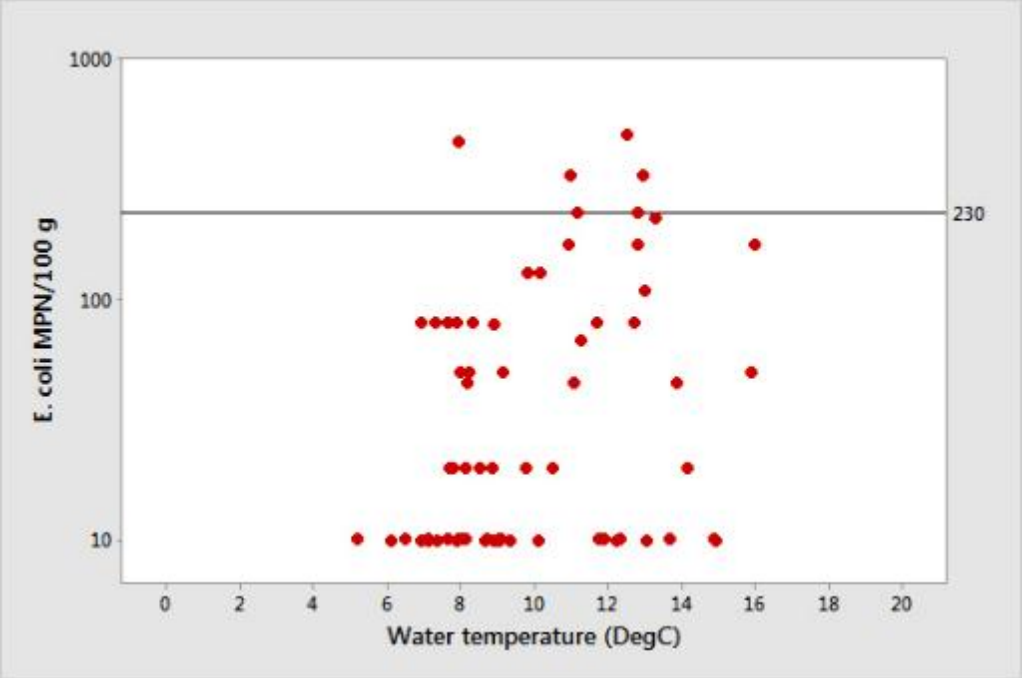


Figure 11.9 Scatterplot of *E. coli* results against water temperature at Loch Ewe

A significant correlation was found between *E. coli* results and water temperature (Spearman's rank correlation r = 0.289, p = 0.018). The greatest proportion of low results were seen in samples taken at temperatures <10^{o}C.

11.6.4 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence and hence freshwater borne contamination at a site. A scatterplot of *E.* coli results against salinity for Loch Ewe is shown in Figure 11.11. Salinity was recorded for 35 out of the 70 samples and jittering of results was applied at 0.02 (x-axis) and 0.001 (y-axis) respectively.

No significant correlation was found between common mussel *E. coli* results and salinity (Spearman's rank correlation: r = -0.195, p = 0.260).

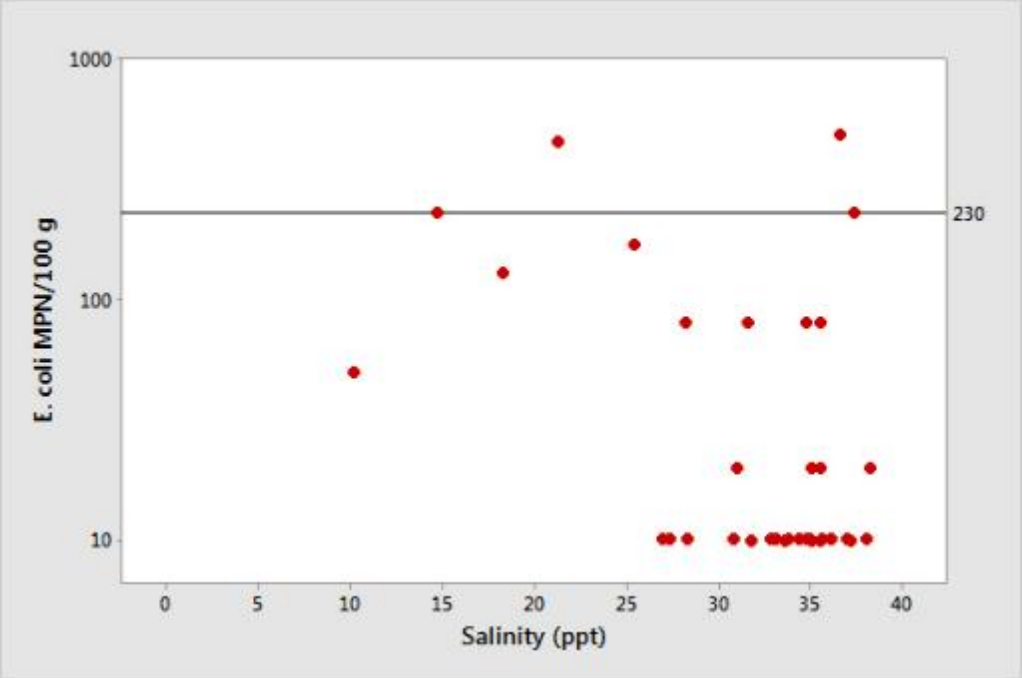


Figure 11.10 Scatterplot of *E. coli* results against salinity at Loch Ewe

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

Four king scallop samples yielded results >230 *E. coli* MPN/100 g. These are listed in Table 11.2.

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

Collection Date	*E. coli* (MPN/100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (°C)	Salinity (ppt)	Tidal state (spring/neap)	Tidal State (high/low)
03/11/2009	490	NG 857 888	28.6	52.8	12.4	37	Spring	High
06/03/2012	460	NG 857 888	0.8	12.6	8.0	21	Increasing	Ebb
08/10/2013	330	NG 857 888	38.2	65.8	13.0	-	Spring	High
04/11/2014	330	NG 857 888	-	-	11.1	-	Increasing	Ebb

-No data available

The four elevated Loch Ewe results were from samples taken in 2009, 2012, 2013 and 2014. Two were from samples taken in November, one in March and one in October. The reported sampling location was the same for all four samples, at NG 857 888, which is the current RMP location. Previous two and seven day rainfall was available for three of the four sample results. Rainfall levels were high in two out of the three samples for both the previous two days and previous seven days. Water temperature varied between 8 and 13°C, whilst salinity was recorded for two out of the four samples at 21 and 37 ppt. Two samples were reported to have been taken on high spring tides, whilst the other two were reported to have been taken on ebbing increasing tides.

11.8 Summary and conclusions

Results for both mussels and scallops have generally been low although a much higher maximum results was seen in mussels than in scallops. Detailed analysis was only undertaken for the results from the king scallop samples.

The majority of samples have been taken within the several fishery area which is located on the north side of the Isle of Ewe. The sampling location of a large proportion of the samples has only been reported to 100 m accuracy and the majority of these were identified against a single NGR. An assessment of spatial variability in *E. coli* results was therefore not undertaken.

An increase in contamination levels was apparent between June and November and a significant difference in sample results between seasons was found, with higher results in samples taken in the autumn.

A significant correlation was found between sample results and previous two day rainfall and between results and previous seven day rainfall. This was apparently associated with low *E. coli* results being associated with samples taken after no, or relatively low, rainfall. A significant correlation was also found between sample results and water temperature. No significant correlation was found between the E. coli results and salinity, spring/neap tidal state or between results or high/low tidal state.

12. Designated Waters Data

Shellfish Water Protected Areas

The Shellfish Waters Directive (2006/113/EC) has been repealed (as at 31 December 2013) and equivalent protection for areas previously designated under that Directive is given by The Water Environment (Shellfish Water Protected Areas: Environmental Objectives etc.) (Scotland) Regulations 2013. The Loch Ewe Shellfish Water Protected Area (SWPA) has the same boundaries as the previous Loch Ewe Shellfish Growing Water (SGW). The SWPA designation covers Loch Ewe and Loch Thurrnaig and includes the production area and several fishery. The designated SWPA for Loch Ewe is shown in Figure 12.1. Since 2007, assessment of the bacteriological status of shellfish waters has been undertaken using the shellfish hygiene *E. coli* data and this data has been reviewed in Section 11.

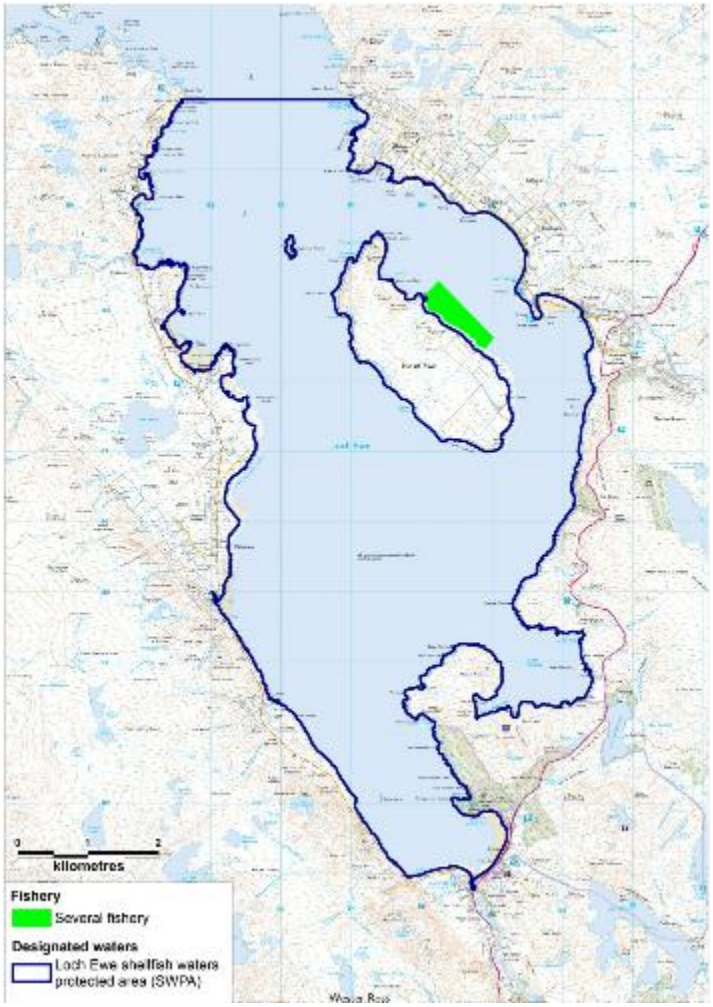


Figure 12.1 Designated shellfish water protected area – Loch Ewe

Bathing Waters

There are no designated bathing waters within Loch Ewe and Loch Thurnaig.

13. Bathymetry and Hydrodynamics

13.1 Introduction

13.1.1 The Study Area

Loch Ewe is situated in the Highland district on the northwest coast of Scotland. It lies in a sparsely populated region and the landscape around the loch is characterised by low hills and numerous freshwater lochs. Streams flow from these lochs and from the surrounding hills into the assessment area along both eastern and western coastlines. A large island, the Isle of Ewe lies in the middle of the assessment area and is approximately 4 km^2 in area. At the southern end of the assessment area lies the adjoining loch, Loch Thùrnaig, separated from the main body of the loch by the protrusion Rubha Àird na Bà. To the west of this peninsula, the River Ewe flows into the assessment area at Kinlochewe.

The assessment area encompasses all of Loch Ewe and Loch Thùrnaig, and the northern assessment area boundary extends between Gob a' Gheoda in the east and Sgeir Maol Mhoraidh. The assessment area is shown in Figure 13.1, with the assessment area demarcated by the red line. The total length of Loch Ewe is 11.9 km (Edwards & Sharples, 1986). At its narrowest point just south of the assessment area boundary, Loch Ewe is approximately 2 km in width, while at its widest it is approximately 5 km in width.

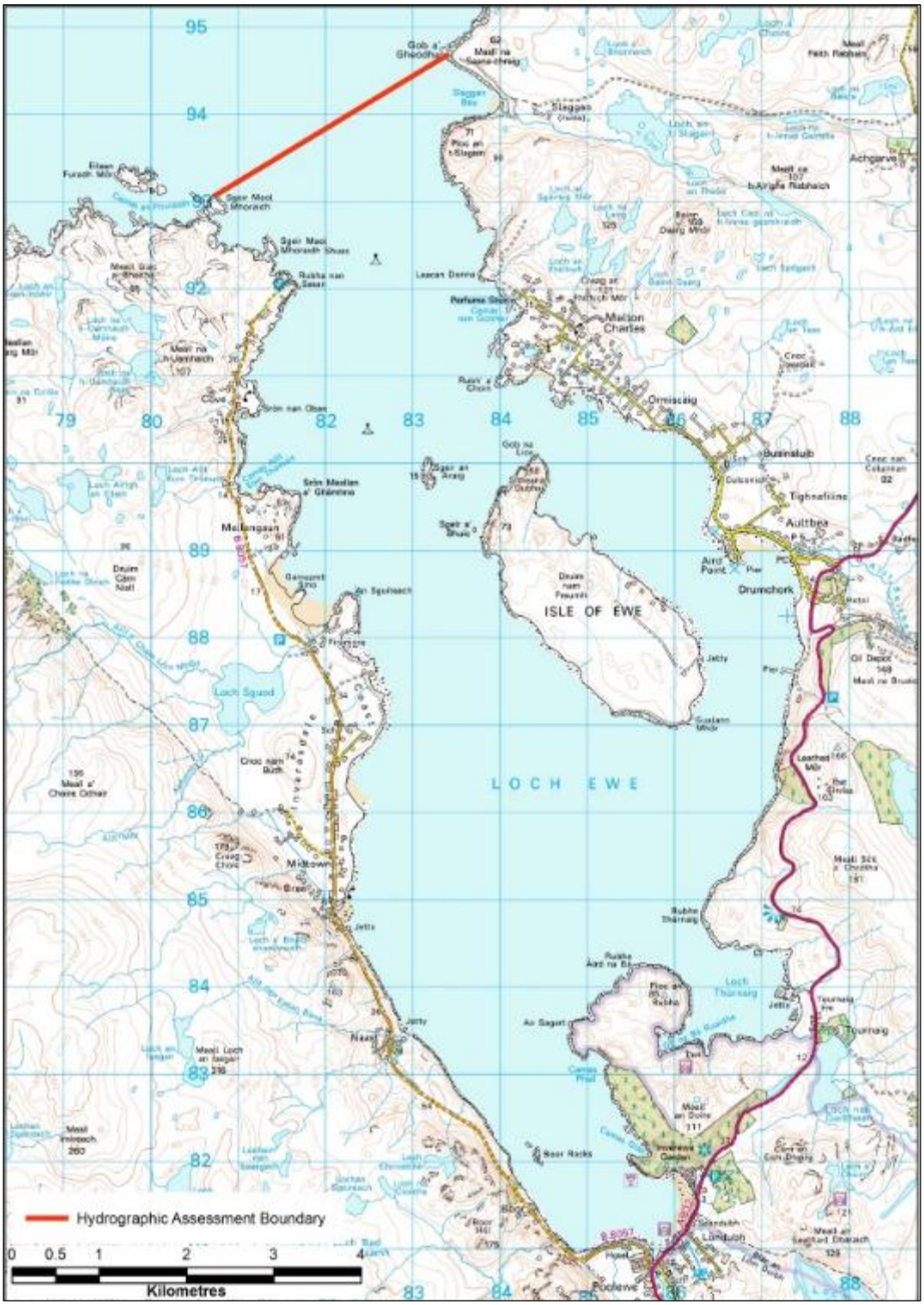


Figure 13.1 Extent of the Loch Ewe hydrographic study area

Coordinates for Loch Ewe:

57.823830°N 005.634597°W, OS NG 820920

13.2 Bathymetry and Hydrodynamics

13.2.1 Bathymetry

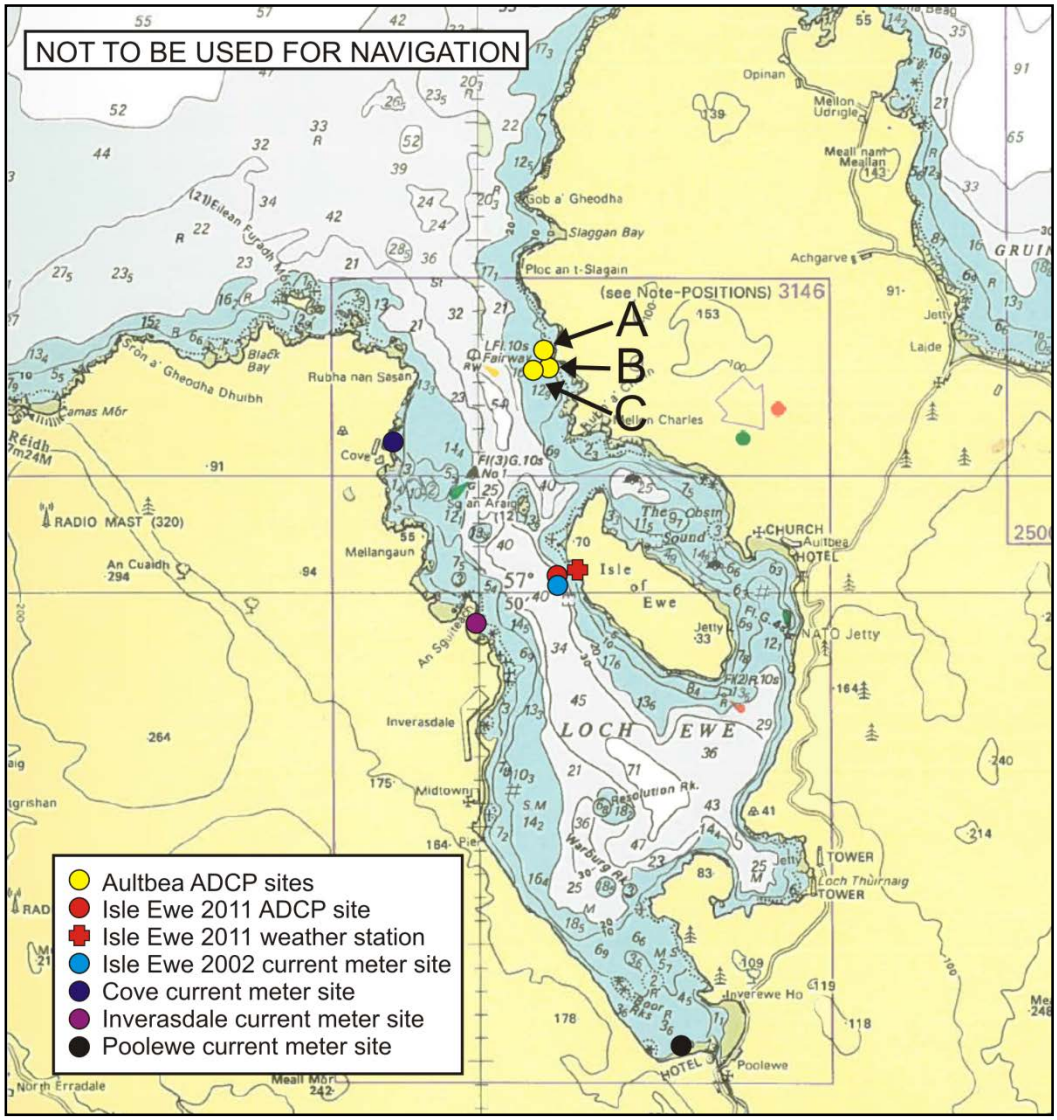


Figure 13.2 Admiralty chart (1794) extract of the Loch Ewe assessment area with ADCP, current meter and meteorological stations shown. © Crown Copyright and/or Database rights. Reproduced by permission of the Controller of her Majesty's Stationary Office and the UK Hydrographic Office (www.ukho.gov.uk).

Figure 13.2 shows the bathymetry of Loch Ewe. Two sills are found in Loch Ewe, the deepest of which is found at the entrance to the loch, between Rubha nan Sasan and Ploc an t-Slagain. This sill has a maximum depth of 33 m and a width of 2.36 km at low water (Edwards & Sharples, 1986). The shallower sill is found between An Sguileach and the Isle of Ewe, and includes the tidally exposed rock, Sg an Araig. The maximum depth of the shallower sill is 29 m, while the width at low water is 3.19 km (Edwards & Sharples, 1986).

The deepest point in Loch Ewe is found in the basin to the south of the shallower sill, and reaches a maximum depth of 73 m (Edwards & Sharples, 1986). A second deep

pocket at 54 m depth is found between the two sills. Outside the loch and to the north of the assessment area boundary waters gradually increase in depth to 50 – 60 m.

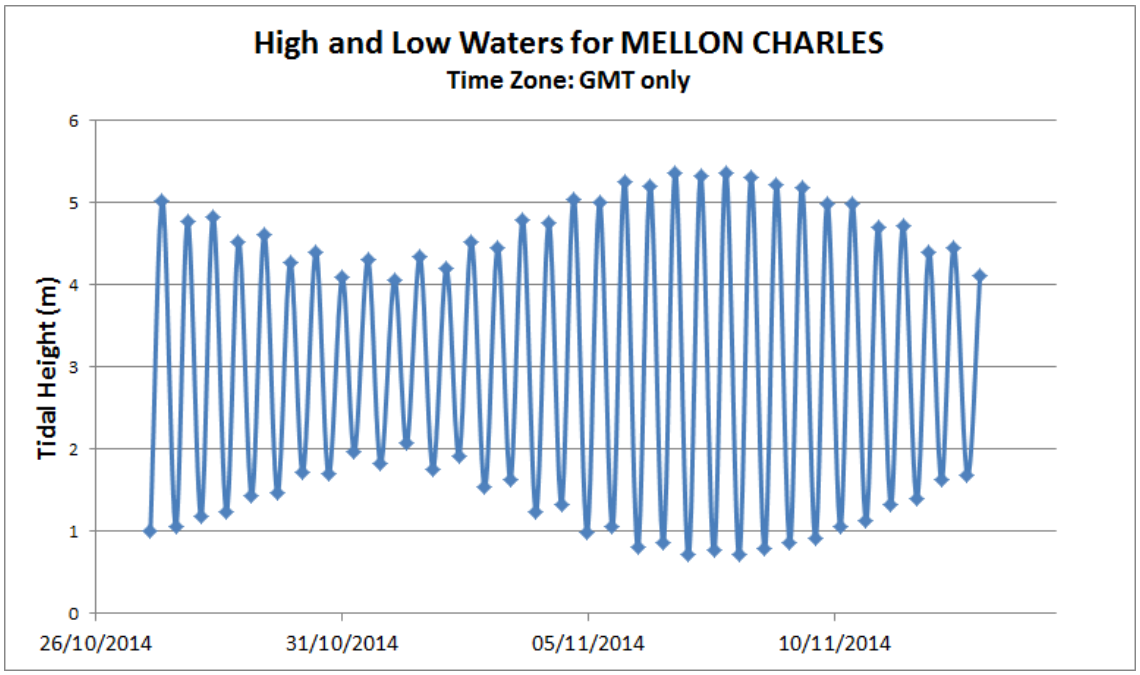
Within Loch Ewe it is worth noting that water depths differ substantially on either side of the Isle of Ewe. The channel to the south west of the Isle of Ewe ranges from 34 - 71 m in depth, while to the north east of the island, waters reach a shallow point of 6.3 m at the narrowest point between the island and the shore. The southernmost portion of Loch Ewe is comprised of two embayments: a broad, gently shallowing bay to the south of the Boor Rocks, and the deeper Loch Thùrnaig to the south and east of Rubha Aird na Bà.

The mean depth of the assessment area at low water is 21.3 m, while the estimated low water volume is 9.45 x 10^8 m^3 (Edwards & Sharples, 1986).

13.2.2 Tides

Data on tidal information is provided based on tidal characteristics determined from Mellon Charles, within the assessment area.

Standard tidal data for Mellon Charles, centred around the survey date of 4th November 2014, are shown in Figure 13.3. Tidal predictions for Mellon Charles indicate that in this region the tidal characteristics are semi-diurnal, with a well-developed spring-neap cycle.



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

Figure 13.3 Two week tidal curve for Mellon Charles.

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

Mean High Water Springs = 5.1 m

Mean Low Water Springs = 0.7 m
Mean High Water Neaps = 3.8 m
Mean Low Water Neaps = 2.0 m

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

Springs: 1.95×10^8 m^3
Neaps: 7.99×10^7 m^3

13.2.3 Tidal Streams and Currents

Where are no published tidal diamonds for this area, off the entrance from Loch Ewe tidal streams can run at up to 1.3 m/s (Lawrence, 1990). Tidal streams can reach speeds of up to 0.5 m/s within the body of the loch (Lawrence, 1990). Some enhancement of the speed of the tidal streams caused by shallow areas and tidally exposed rocks will be important along the length of Loch Ewe.

Current meter data were available at five locations within the assessment area: Aultbea, Isle Ewe, Cove, Inverasdale, and Poolewe. Three current meters were deployed simultaneously at Aultbea during a single survey, while two separate surveys were carried out at the Isle Ewe location (2002 and 2011). Data were obtained from SEPA for these sites, whose locations are shown in Figures 13.2 and 13.4.

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

The surveys at Aultbea and Isle Ewe spanned a period of at least fifteen days, focussing on a half-lunar period in order to capture a spring-neap cycle. The surveys at Cove, Inverasdale, and Poolewe only spanned a period of 5 days. The survey period and location of each current meter is outlined in Table13.1.

Table 13.1 Locations and sampling dates for Loch Ewe current meter data.

Survey Site	Location	Sampling Period	Citation
Aultbea A	57.8679°N 005.6471°W	25 Jul 2007 – 8 Aug 2007	Anderson Marine Surveys 2007
Aultbea B	57.8659°N 005.6478°W	25 Jul 2007 – 8 Aug 2007	Anderson Marine Surveys 2007
Aultbea C	57.8655°N 005.6489°W	25 Jul 2007 – 8 Aug 2007	Anderson Marine Surveys 2007
Isle Ewe 2002	N/A	31 Dec 2001-15 Jan 2002	ERT (Scotland) Ltd 2002
Isle Ewe 2011	57.8340°N 005.6459°W	10 Jun 2011 – 25 Jun 2011	Marine Harvest 2011
Cove	57.8552°N 005.6896°W	20 Jul 2007 – 25 Jul 2007	Anderson Marine Surveys 2008
Inverasdale	57.8281°N 005.6664°W	20 Jul 2007 – 25 Jul 2007	Anderson Marine Surveys 2008
Poolewe	57.7695°N 005.6075°W	20 Jul 2007 – 25 Jul 2007	Anderson Marine Surveys 2008

At Aultbea, two current meters were deployed at each station, one sub-surface, and one at mid-water (reported as ‘bed’ in Anderson Marine Surveys 2007). At station A, the water depth was 6.4 m, at station B, water depth was 3.2 m, and at station C, water depth was 10 m. Current data from Aultbea are summarised in Table13.2.

Mean current speeds at Aultbea are slightly stronger at the surface than at the seabed, with the greatest difference at station C, corresponding with the deepest water depth. Currents at station C flowed in a clear northwest – southeast direction, both at the surface and at the seabed, while currents at stations closer to shore (A and B) were more variable, particularly at the shallowest station, station B. Residual flows at stations A and B suggest advection towards the southeast, following bathymetric contours, while residual currents further offshore at station C flow in a more south-westerly direction. This site (station C) was also determined to be the most dispersive of the three (Anderson Marine Surveys 2007). While no weather data were available at Aultbea for the duration of the survey, it is worth noting that at shallow stations such as these, wind speed and direction would likely have an important influence on current flows and direction. For instance, there was a substantial increase in current velocities at all stations between the 6th and 7th of August that could have been the result of strong winds influencing current speeds.

Table 13.2 Aultbea current data measured in 2007

	Station A		Station B		Station C	
	Near-bed	Surface (6.4 m above seabed)	Near-bed	Surface (3.2 m above seabed)	Near-bed	Surface (10 m above seabed)
Mean Speed (ms^{-1})	0.037	0.060	0.078	0.110	0.079	0.141
Maximum Speed (ms^{-1})	0.164	0.186	0.380	0.535	0.290	0.415
Principal Axis Amp & Dir (ms^{-1}) & (^oM)	0.042 (015)	0.082 (185)	0.104 (195)	0.161 (355)	0.120 (165)	0.206 (165)
Residual speed (ms^{-1})	0.009	0.016	0.028	0.021	0.010	0.012
Residual direction (^oM)	43.78	156.16	152.83	187.48	250.51	235.95

Current meter data was also recorded at two different sites on the western shore of the Isle of Ewe in 2002 and 2011. Mean water depth at the 2002 deployment site was 21.4m (ERT (Scotland) Ltd, 2002), while mean water depth at the 2011 site was 42.9 m (Marine Harvest, 2011). In 2002, meteorological data were collected from the Met Office meteorological station at Aultbea, while in 2011 a weather station was deployed on the Isle of Ewe. Isle Ewe current data recorded in 2002 are summarised in Table13.3, while data recorded in 2011 are summarised in Table13.4.

The use of a Doppler current meter at Isle Ewe in 2002 means that water velocities close to the surface have not been measured effectively because of the characteristics of the acoustic beam. Doppler current meters cannot measure the upper 15% of the water column (RDI, 1996), so in 21.4 m of water at Isle Ewe the meter is limited to measurements below 3.2 m water depth. Therefore, the reported values in the 'surface' and '3 m' bins in table13.3 are unreliable and have not been used further in this study.

Calculated mean current speeds at this station and the maximum current speeds towards the surface suggest that flows are strong at this site. This may be the result of meteorological conditions acting on current flows at the surface. Wind speeds recorded in 2002 were rarely below 10 ms^{-1}, and averaged 12.6 ms^{-1} (Beaufort Force 6) for the duration of the sampling period (ERT (Scotland) Ltd, 2002). Current flows in 2002 were in an eastern direction near the sea surface, gradually shifting in a south southeasterly direction near the sea bed. Residual currents, on the other hand, flowed towards the north.

Table 13.3 Isle Ewe current data measured in 2002. Doppler current meter measurements are not reliable near the surface and so the 'surface' and '3 m' depth bins have not been used in this study. See section 2.3.8.

Average Depth	Surface	3 m	6 m	8.5 m	11.5 m	14.5 m
Mean Speed (ms^{-1})	0.630	0.252	0.129	0.111	0.065	0.051
Maximum Speed (ms^{-1})	1.01	0.55	0.66	0.60	0.31	0.18
Principal Axis Amp & Dir (ms^{-1}) & (^oM)	0.543 (93.23)	0.269 (85.40)	0.261 (104.3)	0.271 (104.14)	0.160 (111.3)	0.138 (119.5)
Residual speed (ms^{-1})	0.566	0.221	0.100	0.074	0.035	0.024
Residual direction (^oM)	371.4	10.6	347.7	352.2	347.0	342.4

Mean recorded current speeds in 2011 are similar to those measured in 2002 at 6 m and deeper depths, as are the predominant current directions. Residual currents, however, are somewhat similar in speed but flow in a more westerly direction, which may be reflective of the deeper bathymetry causing flows to align with the axis of the deep channel between the Isle of Ewe and the western mainland shore of Loch Ewe. In contrast to 2002, wind speeds during the 2011 survey rarely reached 10 ms^{-1} over the duration of the survey (Marine Harvest, 2011).

Table 13.5 Isle Ewe current data measured in 2011

Average Depth	Surface (35.7 m above seabed)	Mid-water (24.7 m above seabed)	Bottom (2.7 m above seabed)
Mean Speed (ms^{-1})	0.108	0.080	0.078
Maximum Speed (ms^{-1})	0.280	0.227	0.224
Principal Axis Amp & Dir (ms^{-1}) & (^oM)	0.247 (110)	0.215 (114)	0.173 (101)
Residual speed (ms^{-1})	0.052	0.026	0.042
Residual direction (^oM)	235.6	220.1	318.6

Current meter data were collected simultaneously at three further locations in Loch Ewe in 2007: Poolewe, Inverasdale, and Cove. Two meters were deployed at each site, at the surface and at near the sea bed, though no water depth information was available for these locations.

Each survey during this campaign lasted five days, spanning only a portion of the spring-neap tidal cycle. They can, however, provide some insight into current flows at these sites in comparison with Aultbea and Isle Ewe.

Current flows at Poolewe at the southernmost end of Loch Ewe are predominantly oriented northeast-southwest, parallel to the orientation of the shores of the southernmost embayment of Loch Ewe. Current speeds here are low in comparison with other surveyed sites in Loch Ewe, though this may be a result of the shallow

bathymetry of the bay at Poolewe and of the sampling site, which appears to be in 1 – 2 m of water (Figure 13.2).

Table 13.6 Current data from Poolewe, Inverasdale, and Cove measured in 2007 (Anderson Marine Surveys , 2008)

	Poolewe		Inverasdale		Cove	
	seabed	**surface**	**seabed**	**surface**	**seabed**	**surface**
Mean Speed (ms^{-1})	0.004	0.033	0.048	0.060	0.031	0.020
Maximum Speed (ms^{-1})	0.045	0.089	0.082	0.155	0.055	0.066
Principal Axis Amp & Dir (ms^{-1}) & (^oM)	0.094 (165)	0.041 (345)	0.031 (005)	0.056 (075)	0.003 (045)	0.003 (045)
Residual speed (ms^{-1})	0.013	0.024	0.045	0.045	0.032	0.032
Residual direction (^oM)	224.0	359.7	359.4	48.7	40.4	40.4

Of the sites surveyed in 2007, currents speeds are fastest at Inverasdale. This site is located near the narrowest point of the loch to the west of the Isle of Ewe, where currents are likely to be enhanced. While no specific depth information was available, from bathymetric charts this site appears to be situated in < 3m of water (Figure 13.2), where bottom friction is likely to slow current speeds. Current flows at this site are substantially slower than at sites on the opposite side of the deep channel, along the shores of the Isle of Ewe where bathymetry slopes more steeply towards the deepest parts of Loch Ewe.

Currents at Inverasdale are oriented in a north-south direction at the seabed, though surface currents flow in a more northeasterly direction. Circulation at this site may also be influenced by shoreline topography and the adjacent headland at An Sguiteach.

Currents at Cove at both the seabed and the sea surface flow in a predominantly northeasterly direction towards the mouth of Loch Ewe. Unlike the other two locations surveyed in 2007, measured current speeds are greater near the seabed than at the surface. However, once again there is little information regarding the sampling depth of this station, though it is likely to be in waters 2 – 3 m deep (Figure 13.2).

Weather data were also recorded from a nearby Met Office weather station during the 2007 survey. Wind speeds were generally low, with a maximum of 3.5 m/s, so wind forcing is unlikely to have substantially influenced measured current flows at these three sites.

In general, the current meter data from across Loch Ewe suggests that this loch is well flushed, with particularly strong currents in the vicinity of the west side of the Isle

of Ewe. From available current meter data, dispersion in Loch Ewe is suggested to be rapid. Dispersion is likely to be further enhanced around sills, headlands, and the numerous shallow and/or tidally exposed rocks in Loch Ewe.

Loch Ewe experiences greater wave action than many other Scottish sea lochs (Connor & Little, 1998), which could further enhance dispersion within Loch Ewe. Sources of wave energy are from both short period waves generated within the Loch itself and longer period swells originating from the waters to the west and northwest of the entrance to the Loch, which is open to the Minch.

Using the largest recorded mean surface principal current of 0.261 m/s (discounting surface and 3 m measurements from Isle Ewe in 2002: see Table 13.3 and text in 2.3.7) and assuming a uniform sinusoidal tide, the cumulative transport that might be expected during each phase of the tide (approximately 6 hours) has been estimated for the Loch Ewe assessment area as 3.6 km (based on a surface principal current amplitude of 0.261 m/s). No distinction is made here for springs and neaps.

13.2.4 River/Freshwater Inflow

One major river, the River Ewe, flows into Loch Ewe at its southern end near the village of Poolewe. Numerous other small streams and burns flow into Loch Ewe from the surrounding hills and nearby freshwater lochs. Larger lochs whose associated streams flow into Loch Ewe include Loch Allt Eoin Thomais, Loch Sguod, and Loch Chriostina on the western side of Loch Ewe and Loch nan Dailthean, Loch a'Bhaid-Luachraich, and Loch an Fhithich on the eastern side of Loch Ewe.

The annual precipitation in the area is approximately 1750 mm and the annual freshwater runoff is estimated as 855.6 M m^3 yr^{-1} (Edwards & Sharples, 1986). The ratio of freshwater flow to tidal flow in Loch Ewe is 1:110, a relatively moderate ratio for Scottish sea lochs.

13.2.5 Meteorology

The meteorological station Aultbea No 2 is the nearest weather station for which a complete rainfall data set was available, situated near the northeastern shore of the assessment area. Rainfall records are available from January 2008 to December 2013.

While 2010 generally had the lowest daily rainfall, the highest rainfall for this time period was recorded in 2011 (1695 mm). A single high rainfall event of > 40 mm d^{-1} occurred in 2012, while rainfall events of > 30 mm d^{-1} were recorded in all years. These rainfall events (>30 mm d^{-1}) occurred in all months except February – April, and June. Daily rainfall values varied seasonally, and were generally lower in the summer months (April - July) and higher in winter months (October - December). Mean rainfall at Aultbea No. 2 peaks in November. For the duration of the dataset,

daily rainfall below 1 mm occurred on 43% of days, while daily rainfall above 10 mm occurred on 11% of days.

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

Wind data were obtained from Stornoway Airport, located 60 km to the northwest of the assessment area. Given the distance between these two locations and varying topography, wind statistics may not be directly transferrable to the specific production area in Loch Ewe. They are, however, valuable in providing the general pattern of the seasonal wind conditions. Data collected between January 2004 and December 2013 indicate that the predominant wind direction is from the southwest. Seasonally the strongest winds occurred during the winter and came from this quarter. Typically the wind came from around the south and west throughout the year but the summer also saw winds from the northeast. These two directions lie perpendicular to the axis of the assessment area. Nevertheless, local wind direction in Loch Ewe are likely to be somewhat influenced by the surrounding topography.

13.2.6 Model Assessment

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

The box model quantifies the primary exchange mechanisms. The key outputs from the model with respect to this hydrographic assessment is a series of annual mean values that describe the relative importance of the estuarine (gravity) exchange, tidal exchange, and the flushing time, which is the inverse of the exchange rate. These values are given in Table 13.6

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

Parameter	Value
Tidal Volume Flux (m3 s-1)	195
Estuarine Circulation Volume Flux (m3 s-1)	214
Median Flushing Time (days)	27
95%-ile Flushing Time (days)	38

The ratio of tidal volume flux to estuarine circulation volume flux is around 1 so the estuarine exchange and tidal exchanges are comparable, neither is dominant (Gillibrand, et al., 2013).

The exchange time for the surface and intermediate layers is calculated as 27 days which is much longer compared to the tidal prism estimate of 3.4 days (Marine Scotland, 2012). It is known that the tidal prism method can overestimate exchange rates and the difference suggests that the exchange environment is possibly less efficient than can be captured by a simple tidal exchange approach. This may be a reflection of the rather complex basin structure of the Loch and the relatively high contribution of freshwater to the exchange environment. However, the current flow through the system and the relatively deep sills (around 30m) implies that at least exchange of the upper waters will occur relatively effectively, possibly enhanced by the estuarine flow.

13.3 Hydrographic Assessment

13.3.1 Surface Flow

The site and meteorological data indicate that the discharge of freshwater into the surface will occur around the margin of the loch, with a significant discharge from the river Ewe at the head of the loch. The meteorological data indicate a moderate seasonal variation in freshwater discharge which will mean that the estuarine exchange has a seasonal variation also. Nevertheless, it is apparent from the tidal to freshwater ratio that freshwater discharge is an important aspect of circulation and exchange in this system.

Loch Ewe has some complexity in terms of its topography with shallow shores, a large central island and two basins. Further, tidal flows are found to be moderate and the freshwater contribution a significant proportion of the exchange volume. It is therefore likely that a well-developed surface layer will form in many areas of the loch, particularly towards the head. A distinct fresh surface layer can be more easily influenced by winds giving rise to complex current systems that can vary with depth as seen in the current meter data.

From the current meter records located throughout Loch Ewe it is clear that the flow of water is rather complex and variable in both speed and direction across the assessment area. It is notable that the current meters were generally sited in shallow water where bed effects likely gave rise to differences in flow between the surface and the bottom. Nevertheless, the general characteristic is that the flows will tend to follow the local bathymetry. The cumulative transport distance on each phase (flood/ebb) of the tide has been estimated at around 3.6 km within the assessment area.

The residual flows during the period of measurement were highly variable and in some cases rather large. The variation is most likely due to differences in the wind conditions during each deployment period. Surface residual flows would be enhanced by winds blowing out of the loch from the south. It is likely that this will be rather effective if the local topography steers the wind.

Net transport of contaminants is related to the residual flow documented in Tables 2.3.1-5. The residual flow in the surface waters of the assessment area are shown to be highly variable and will be related to variation in the localised wind and freshwater conditions. Using a value of residual flow speed measured at the surface (0.03 m/s), the net transport over a tidal cycle of approximately 12 hours would be around 1.3 km. This is less than the transport from tidal flow.

From the current meter measurements in Ewe it is likely that any surface contaminant in the loch could be transported effectively out of the loch.

13.3.2 Exchange Properties

The box modelling has shown that the flushing time for the surface and intermediate depth waters within the assessment area is around 27 days. This is much greater than a simple tidal prism approach and may reflect the complexity of exchange that exists in the assessment area. However it is likely that at least the upper waters will be effectively exchange and winds from the south may enhance the effective flushing of the loch. There is potential for a significant estuarine flow and the current meter data suggests that the assessment area has extremely variable flow conditions that are probably related to the location of the measurements, freshwater discharge and wind conditions.

There are a lot of current meter data available for this location which provides an insight into the flow characteristics of Loch Ewe. It is clear that the flows can be highly variable in time and throughout the assessment areas and subject to wind forcing. The current records are relatively short and so it is difficult to assess the seasonal variation in flow and circulation. However, given the data and the output from a simple box modelling exercise, it is possible to provide an assessment of the likely exchange characteristics of the area. The confidence level of this assessment is MEDIUM.

14. Shoreline Survey Overview

The shoreline survey was conducted on the 4th and 5th November 2014. Heavy rain was reported in the 48 hours prior to the survey. Moderate to light rain fell at the start of the first day, whilst the second day was dry.

The fishery consisted of a hand-dived king scallop bed and a suspended long-line tray system. The trays are used to rear juvenile scallops for a year, before they are released to the bed. Approximately 100,000 3-4 mm sized scallops were in the trays at the time of the survey. Harvesting occurs year round on demand and is dependent on stock availability. The harvester (Ms Grant) hopes to secure funding to expand the fishery up to 50 hectares, with the long-line site being used for overwintering juveniles 10-30 mm in size. Ms Grant and her business partner had recently purchased the disused marine research station as part of their operation extension.

No scallop samples could be obtained during the shoreline survey due to the need to collect them by diving. Mussels were collected from the RMP (presumably maintained at the location for biotoxin sampling) and from the two shore locations on the mainland. One of these yielded a result of <18 *E. coli* MPN/100 g and the other two results of 18 *E. coli* MPN/100 g. Two seawater samples taken at the fishery yielded results of 3 and 12 *E. coli* cfu/100 ml. Both showed salinities that were marked less than full strength seawater. CTD casts undertaken at those two locations also showed a reduction in salinity near the surface. The greatest influence was found at the southern end of the fishery: this was the location that yielded the higher *E. coli* result. Three seawater samples taken from the shore on the eastern side of the loch gave results of 100, 66 and 3 *E. coli* cfu/100 ml. These samples showed little to no evidence of freshwater influence.

The Isle of Ewe is uninhabited. Small villages were noted on the surrounding mainland; with Drumchork, Aultbea which contained public toilets, Ormiscaig and Mellon Charles on the eastern shore and Poolewe to the south. A disused campsite was noted south of Mellon Charles, with five static caravans also noted nearby. Two hotels were noted: one in Aultbea which is open all year round and the other in Poolewe. Several B&B's were also observed.

Three community sewage facilities were recorded: one with a metal pipe to shore to the south of Aultbea, a second at Ormiscaig and a third was in Poolewe (presumed to be linked to Poolewe PS). Suspected sewage discharge pipes were also noted below houses at Ormiscaig, Mellon Charles and Aultbea. A suspected ST was also recorded close to Poolewe Hotel.

Ten buoys were noted offshore south of Aultbea. Three fishing boats next to a pier and two smaller boats ashore were noted at Aird. Two more boats and a dredger were on the shore next to the Marine Harvest station in Ormiscaig. Six boats were

also observed at the southern extent of the several fishery area, with a boat also noted further offshore to the northwest of the Isle of Ewe.

Eighteen sheep were recorded in a field above the shoreline on the mailand to the north of the fishery and one horse was seen in a field at Aultbea to the east of the fishery. An old farmhouse with a barn was also observed on the Isle of Ewe.

Aultbea and Poolewe were both small fishing villages, with Mellon Charles, Ormiscaig and Drumchork small crofting villages. An area of land belonging to the MOD was observed on the mainland south of Aultbea. Outside these areas much of the surrounding land was rough grazing and heathland, with some scattered areas of mixed forestry. Land adjacent to the shore was steep in places with rocky sections limiting shore access.

Ten watercourses were sampled during the survey, with freshwater sample results varying between <10 and 410 *E. coli* cfu/100 ml.

Birds were the only wildlife observed during the survey. Common gulls were observed most frequently, with gulls, cormorants, lesser black-backed gulls, herons, hooded crows, mallard ducks, greylag geese and starlings also observed.

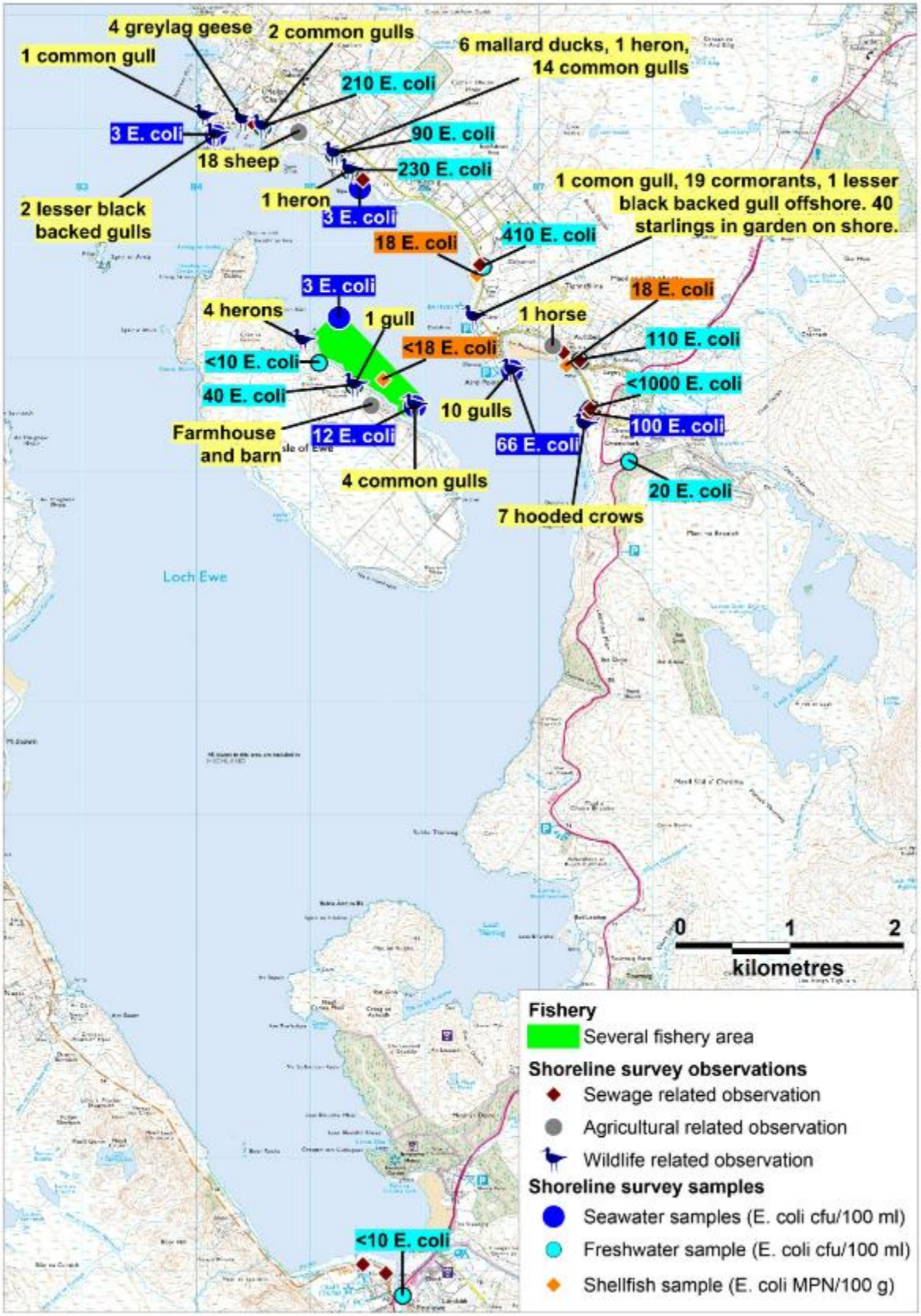


Figure 14.1 Map of shoreline survey observations at Loch Ewe & Loch Thurnaig

15. Bacteriological Survey

A bacteriological survey was not undertaken for Loch Ewe due to the relatively simple nature of the area and the amount of historical *E. coli* monitoring data available for assessment.

16. Overall Assessment

Human sewage impacts

Although the area around Loch Ewe has a relatively low human population, much of this is concentrated on the part of the mainland east and northeast of the fishery. The dwellings on the Isle of Ewe are concentrated along the shoreline adjacent to the fishery.

Much of the area is connected to community sewerage networks, with continuous discharges being located northwest of Mellon Charles (East Loch Ewe STW) and at Poolewe at the head of the loch (Poolewe STW). Several CSOs and EOs are located on the the northeastern side of the loch from Mellon Charles to Drumchork, at Poolewe at the head of the loch, and at Midtown, Inverasdale and Cove on the western side of the loch. Despite the presence of community sewerage networks, a large number of private sewage discharge consents were provided by SEPA. These were for STs located at all of the identified settlements, with a sizeable proportion being identified as discharging to freshwater or seawater. No consents were identified for the Isle of Ewe: it is assumed that the properties located on the eastern side of the island will have septic tanks and that these may impact on water quality adjacent to the island.

Dispersion studies undertaken for the continuous discharges from the East Loch Ewe and Poolewe STWs determined that minimal impact would occur at the several fishery.

Agricultural impacts

Only a small number of farm animals were seen on the eastern mainland shoreline during the shoreline survey. That number of animals would be unlikely to cause a noticeable impact at the fishery. However, land cover data showed the presence of a large area of improved pasture on the mainland and also an area of this on the southeastern part of the Isle of Ewe. A farmhouse and barn was recorded above the shore on the Isle of Ewe adjacent to the fishery during the shoreline survey. It could not be determined whether these were in use for farming. If agriculture is practiced on the northeastern side of the Isle of Ewe, this would have an impact on water quality at the fishery.

Wildlife impacts

The main impact from wildlife on water quality in the vicinity of the fishery is expected to be associated with seabirds. Other intermittent contamination may arise from seals, cetaceans, otters and deer may also occur. It was not possible to predict any consistent spatial variation in such contamination across the fishery.

Seasonal variation

The main seasonal effect with respect to sources is expected to relate to human inputs, with increases in the spring and summer due to tourism and increased boating activity. However, rainfall-dependent CSO discharges are more likely to occur in the autumn and winter. Results from scallop samples taken in the autumn were significantly higher than those from samples taken in spring, summer and winter.

Watercourses

There are a large number of watercourses entering Loch Ewe. The largest is the River Ewe at the head of the loch. However, at the time of the shoreline survey, the *E. coli* concentration was less than the limit of detection of the test. This combined, with information from the Poolewe tracer dispersion studies, indicate that the river should not impact at the several fishery.

Several other watercourses were measured and sampled during the shoreline survey. Most of these, and the ones showing the highest predicted *E. coli* loadings, were located on the mainland to the east and northeast of the fishery. These will impact on water quality between the mainland and the Isle of Ewe but the effect at the fishery itself will depend on the direction and distance of particle transport. More direct impact at the fishery will arise from the two watercourses that were recorded on the eastern side of the Isle of Ewe. One had *E. coli* levels below the detection limit of the test at the time of the shoreline survey but the other had a moderate predicted *E. coli* loading. The latter watercourse will have greatest effect on the central part of the fishery adjacent to the shore.

Movement of contaminants

The flow of water within the loch was determined to be complex and variable in both speed and direction. However, in general, flows will tend to follow the local bathymetry. The cumulative transport distance on each phase (flood/ebb) of the tide was estimated at around 3.6 km. It was expected that a well-developed surface layer would form in many areas of the loch, particularly towards the head. CTD casts undertaken at the northern and southern extents of the several fishery area showed reductions in salinity at the surface, with the greatest effect seen at the southeastern end.

Geographical and temporal patterns of sampling results

No assessment could be undertaken of any spatial patterns in the historical *E. coli* data due to the manner in which sampling locations have been reported. The scallop results have shown a general increasing trend although the frequency and magnitude of peak results hasn't changed over time.

Water quality data collected in the vicinity of the several fishery during the Poolewe dispersion study and during the 2014 shoreline survey showed a tendency for higher results towards the southeastern end of the Isle of Ewe.

Conclusions

Most sources of contamination in the general area of the fishery relate to sewage discharges and watercourses located on the mainland. Septic tank arrangements and agricultural activity on the Isle of Ewe could not be determined. Two watercourses were identified on the island, one of which was determined to have an impact on water quality at the fishery. CTD casts and seawater samples taken during the shoreline survey indicated a potential for a greater level of contamination at the southeastern end of the fishery.

17. Recommendations

A summary of the recommendations is shown on the map in Figure 17.1.

Production area

It is recommended that the extent of the production area be reduced in order to explicitly exclude identified major sources of pollution (predominantly the community continuous and intermittent discharges and larger private discharges) while still encompassing the full extent of the several fishery. The recommended boundaries are as follows: the area bounded by lines from NG 8450 9000 to NG 8510 9000 to NG 8670 8800 to NG 8623 8800 and extending to MHWS.

RMP

It is recommended that the RMP be moved to the southeast of the present location in order to reflect potential impacts from sources at the southeastern end of the Isle of Ewe and also the available water quality data showing higher faecal coliform/*E. coli* levels at that end. The recommended locations is: NG 8580 8867.

Tolerance

As this is a ranched area, with scallops gathered by diving, it is recommended that a 100 m tolerance be applied to allow for variation in density of animals.

Depth of sampling

Not applicable.

Frequency

It is recommended that monitoring be undertaken monthly.

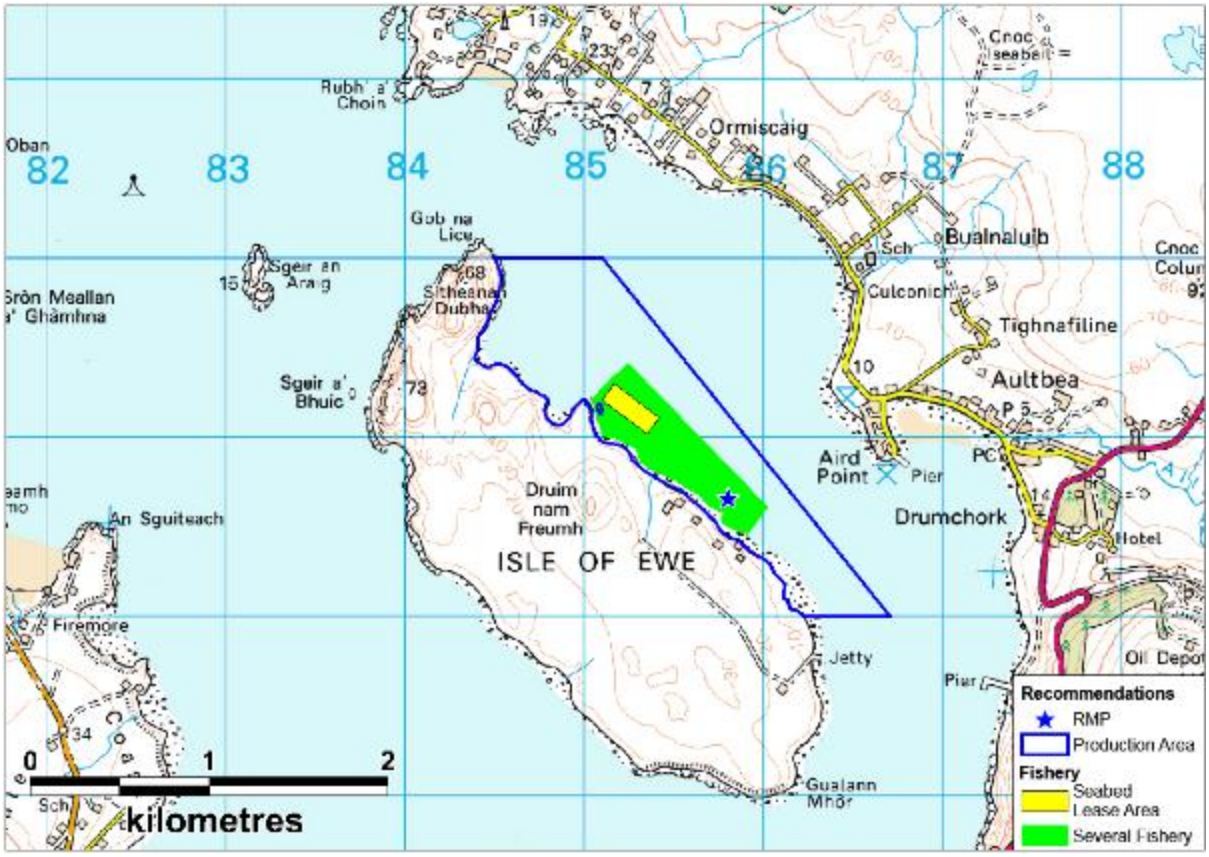


Figure 17.1 Map of recommendations at Loch Ewe And Loch Thurnaig

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1. General Information on Wildlife Impacts

Pinnipeds

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

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

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

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

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

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

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

Cetaceans

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

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

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

Birds

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

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

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

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

Deer

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

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

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

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

Otters

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

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

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2. Tables of Typical Faecal Bacteria Concentrations

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

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

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

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

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

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

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

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

Source: (Gauthier & Bedard, 1986)

References

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

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3. Statistical Data

One-way ANOVA: logec versus Season

```
Method

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

Equal variances were assumed for the analysis.


Factor Information

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


Analysis of Variance

Source  DF  Adj SS  Adj MS  F-Value  P-Value
Season   3   3.151  1.0503     4.21    0.009
Error   66  16.470  0.2495
Total   69  19.621


Model Summary

       S    R-sq  R-sq(adj)  R-sq(pred)
0.499539  16.06%     12.24%       5.57%


Means

Season   N    Mean   StDev       95% CI
1       18   1.376   0.489  ( 1.141,  1.611)
2       18   1.328   0.494  ( 1.093,  1.563)
3       17   1.844   0.597  ( 1.602,  2.086)
4       17  1.3482  0.3991  (1.1063, 1.5901)

Pooled StDev = 0.499539
```

Tukey Pairwise Comparisons

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

Season   N    Mean  Grouping
3       17   1.844  A
1       18   1.376    B
4       17  1.3482    B
2       18   1.328    B

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

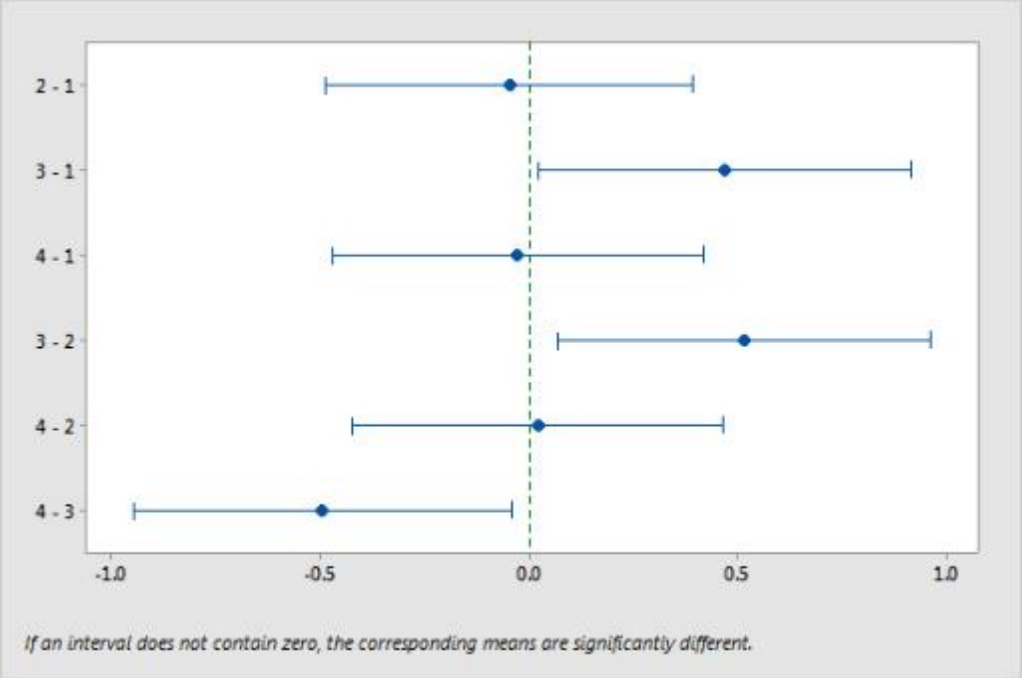

Figure 1 Tukey Pairwise for results from Loch Ewe and Loch Thurnaig King Scallop fishery

4. Hydrographic Assessment Glossary

The following technical terms may appear in the hydrographic assessment.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5. Shoreline Survey Report

Shoreline Survey Report

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

Document Number	B0067_Shoreline 0043

Revision History

Revision	Changes	Date
A	Issue for internal review.	14/11/2014
B	Issue for internal review.	12/12/2014
01	First formal issue to client	15/12/2014
02	Second issue to client including corrections from issue01	12/01/2015

	Name & Position	Date
Author	Eilidh Cole & Debra Brennan	14/11/2014
Checked	Andrea Veszelovszki	12/01/2015
Approved	Mark Hart	12/01/2015

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

Production area:	Loch Ewe & Loch Thurnaig
Site name:	Loch Ewe
SIN:	RC-142-250-07
Species:	King Scallops (*Pecten maximus*)
Existing RMP:	NG 8570 8880
Harvester:	Ms Jane Grant
Local Authority:	Highland Council: Ross & Cromarty
Status:	Existing area
Date Surveyed:	03/11/2014 – 05/11/2014
Surveyed by:	Eilidh Cole & Debra Brennan

Area Surveyed

Approximately 6 km of the eastern shoreline of Loch Ewe starting near Drumchork heading northwest until Sgeirean Mòra at Mellon Charles. Approximately a further 1 km was surveyed on the eastern shoreline of Isle of Ewe starting at Sgeir na h-Airde-fraoich heading southwards. A very short section of shoreline was also surveyed in the Poolewe area beginning at the Poolewe Hotel heading west for approximately 0.5 km.

19. Weather

Heavy rainfall occurred 48 hours prior to the survey on the 2nd and 3rd of November.

On the first day of the survey, Tuesday the 4th of November, there was moderate rainfall with showers for most of the morning. The rain cleared by approximately 14:00 hours with only a few light showers later on in the day. Temperature was around 6°C with a northerly wind of around 21 mph. It was overcast with around 85% cloud cover and the sea state was choppy.

On Wednesday the 5th November, there had been overnight rain but this had cleared by early morning. During the day it was bright and clear with no rain. There was a very light north-easterly breeze with cloud cover at around 75% but clearing throughout the day. Temperature was about 9°C and the sea state was calm.

20. Stakeholder engagement during the survey

Prior to the survey the sampling officer, Mr Bill Steven, was very helpful and provided useful information regarding the survey site and fishery. The survey team were able to meet with Mr Steven on the first day of the survey where he provided further information.

On the second day of the survey (5th November), the survey team met with the shellfish harvester Ms Jane Grant who kindly took the survey team out on

her boat to collect seawater and shellfish samples and to collect CTD cast data. Ms Grant was very helpful and provided further details regarding her fishery.

21. Fishery

King scallops (*Pecten maximus*) are cultivated within the Loch Ewe and Loch Thurnaig fishery. The shellfish are hand-dived and harvest can take place all year round but only when the shellfish are mature enough and when there is a demand for them.

Approximately 100,000 young scallops of approximately 3-4 mm size are on the site at present where they are grown for a year in trays suspended from long lines. After approximately one year, when they are large enough, they are released into the wild to produce a natural stock.

Ms Grant informed the team that she hoped to expand her shellfishery up to 50 hectares, with the longline site remaining the same, which will only be used for overwintering of young juveniles between 10-30 mm in size. There is no consideration of the introduction of any other species however the disused marine research station at waypoint 28 has recently been purchased by herself and her business partner, as part of the extension of their operations. Any plan on future expansion to their current operation is dependent on them getting sufficient funding.

As scallops are hand-dived and unavailable for collection, a common mussel (*Mytulis edulis*) sample was collected from the RMP at waypoint 43 as a substitute.

22. Sewage Sources

The shoreline surrounding the shellfishery at Loch Ewe and Loch Thurnaig is a largely inhabited area with several small villages running the length of the eastern shoreline from south to north. These include Drumchork to the south then Aultbea, Ormiscaig and Mellon Charles heading north. The village of Poolewe lies directly at the head of Loch Ewe.

The Isle of Ewe is also inhabited with a scattering of dwelling places on its eastern shore.

Public facilities were observed in Aultbea including public toilets and a hotel at waypoint 11. No obvious sewage discharges were observed coming from neither any of these facilities nor any of the nearby dwellings, although any pipes observed near these areas were noted and sampled where possible.

23. Seasonal Population

No official campsites or caravan parks were seen in the area surrounding the production area at Loch Ewe and Loch Thurnaig. However, there was a disused campsite at waypoint 29 and five static caravans were observed at waypoint 31. There was one hotel in Aultbea which is open all year round and another in Poolewe. A few B&B establishments were observed but other than this no other hotels, or holiday lets were observed in the area.

24. Boats/Shipping

A number of boats were observed during the survey at Loch Ewe and Loch Thurnaig. Three fishing boats were observed next to the pier at waypoint 12 and two smaller boats were on the shore at waypoint 13. A further two boats and a dredger were on the shore next to the Marine Harvest station at waypoint 20. Six boats were also observed at waypoint 42 and one boat was seen further out to sea at waypoint 44.

Farming and Livestock

There were eighteen sheep in a field above the shoreline at waypoint 33 and one horse in a field next to the road at waypoint 51. One farm was observed on the Isle of Ewe but no animals or livestock were seen. No other farms or livestock were observed during the survey.

25. Land Use

Aultbea and Poolewe are both predominantly fishing villages whereas Mellon Charles, Ormiscaig and Drumchork are mostly small crofting villages. The land surrounding Loch Ewe and Loch Thurnaig, beyond these villages, appears to be mostly used for rough grazing and small crofts. An area of land belonging to the MOD was observed at waypoint 2, although the extent of this area could not be determined. A disused campsite was located at waypoint 29 and a disused marine research station (recently purchased by Jane Grant and partner) was located at waypoint 28.

Land Cover

The predominant land cover surrounding Loch Ewe and Loch Thurnaig is rough grazing and heathland with some scattered mixed forestry. The land is steep in places with rocky sections immediately next to the shore.

Watercourses

Nine watercourses were marked on the survey map to be sampled during the survey and all of these were sampled successfully. One extra freshwater sample, LEFW2 was also taken from a pipe at waypoint 7.

Of the watercourses sampled, the largest was the River Ewe at waypoint 36. Measurements of width, depth and flow were not recorded for this river as it was not required according to the sampling plan.

The Allt Beithe river at waypoint 10 was the next largest at 11 m 43 cm in width followed by the Allt an Raoin Chiuaidh watercourse at waypoint 15 which was 6 m 62 cm in width . All the other watercourses which were sampled were significantly smaller ranging from the Allt Bhruachan Ruadha watercourse located at waypoint 21 which was 2 m 28 cm to the unnamed watercourse at waypoint 45 which was just 28 cm width.

Wildlife/Birds

Wildlife surrounding Loch Ewe and Loch Thurnaig was fairly abundant and a range of birds were observed during the course of the survey.

Common gulls (*Larus canus*) were observed frequently throughout the course of the survey with ten observed at waypoint 13 and one common gull and one lesser black-backed gull (*Lanus fuscus*) on a concrete structure at waypoint 14. Nineteen cormorants (*Phalacrocorax carbo*) were also observed on this concrete structure. A further fourteen gulls were observed on some rocks close to the shore at waypoint 24 and one gull was flying overhead at waypoint 26. At waypoint 27, two lesser black-backed gulls were swimming on the water and at waypoint 31, two common gulls were seen flying overhead. A further four common gulls in total were observed at waypoint 42.

Herons (*Ardea cinerea*) were also observed throughout the survey. One heron was observed on the shore at waypoints 22 and 24 and four more were observed at waypoint 44. Ms Grant also noted that there was a heron colony in the trees next to the shore near to waypoint 44.

Other birds observed during the survey included seven hooded crows (*Corvus corone cornix*) at waypoint 4 and approximately forty starlings (*Sturnus vulgaris*) in a garden at waypoint 14. Six mallard ducks (*Anas platyrhynchos*) were observed at waypoint 24 and four greylag geese (*Anser anser*) were flying overhead at waypoint 28.

No other wildlife was observed during the course of the survey.

Specific observations made during the survey are mapped in Figures 1 and 2 and listed in Table 1. Water and shellfish samples were collected at the locations marked in Figure 3. Bacteriology results are given in Tables 2 and 3. Photographs are presented in Figures 4 – 15.

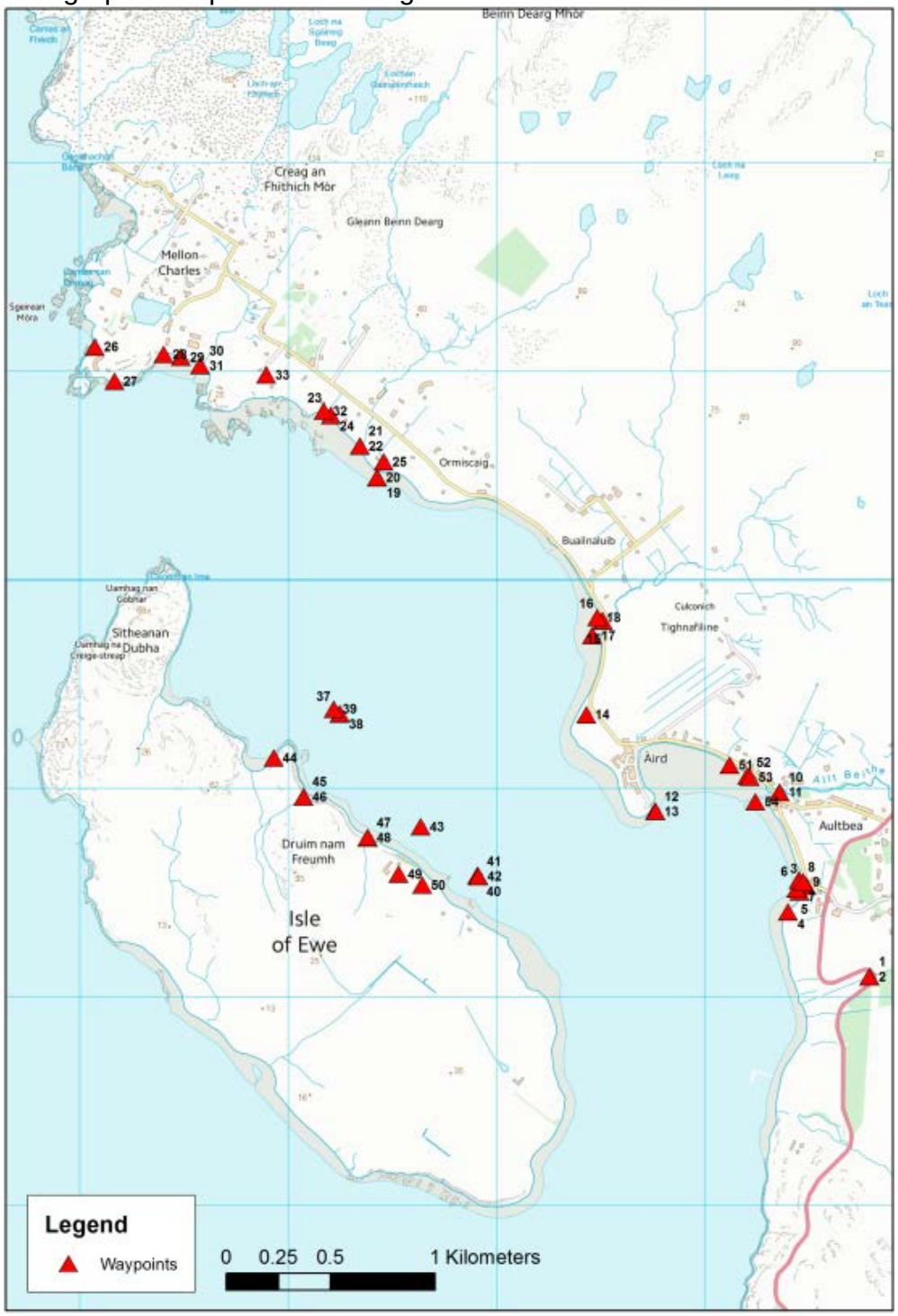

Figure 1. Loch Ewe & Loch Thurnaig waypoints north

Figure 2. Loch Ewe and Loch Thurnaig waypoints south

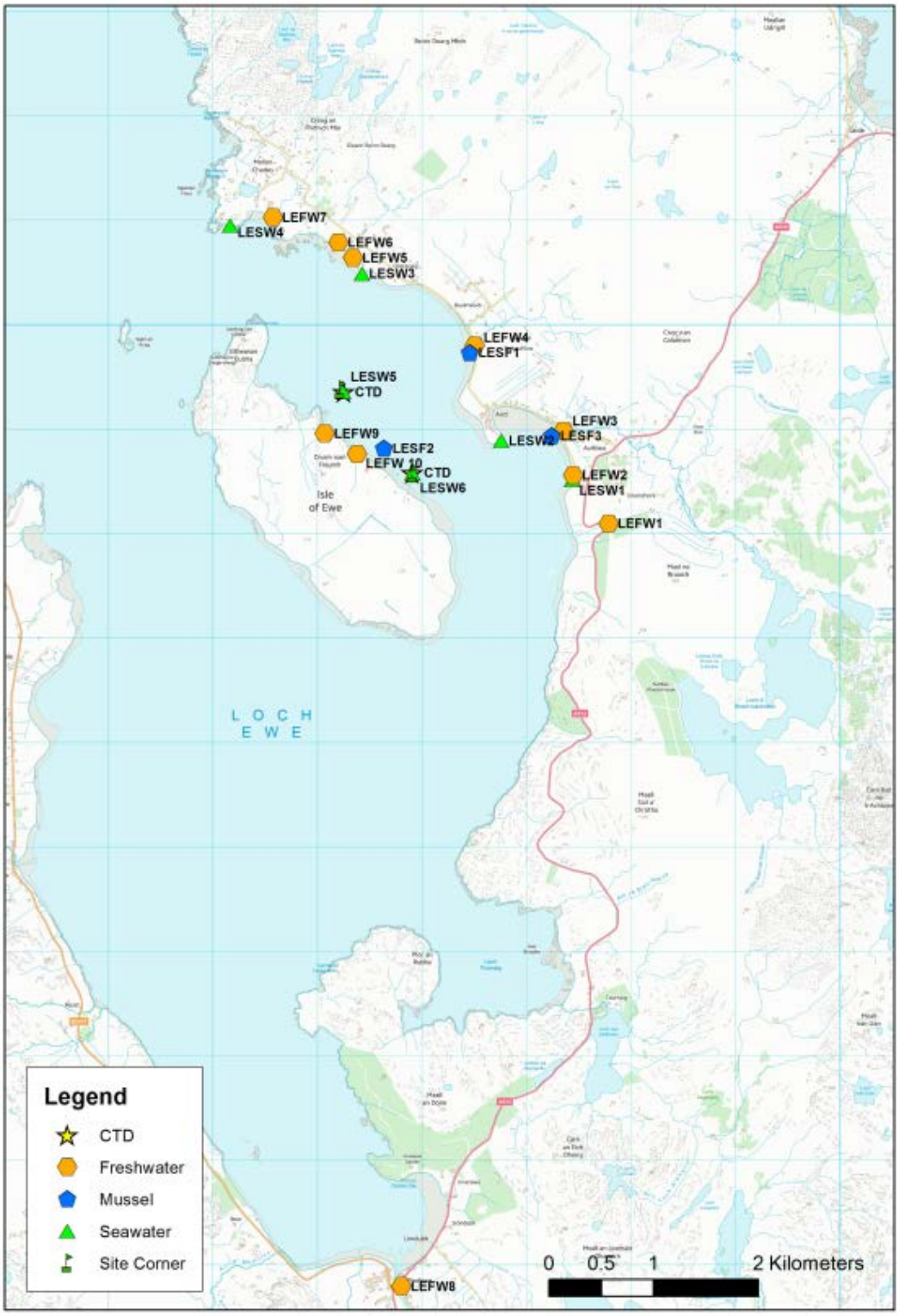

Figure 3. Loch Ewe and Loch Thurnaig samples

Table 1 Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
1	04/11/2014	9:19	NG 87788 88097	187788	888097		LEFW1	Planned freshwater sample from unnamed watercourse. Sample associated with waypoint 2.
2	04/11/2014	9:19	NG 87787 88096	187788	888097	Figure 4		Planned freshwater sample taken from small unnamed watercourse. OPA oil fuel depot further in shore beside river. Width - 88cm; Depth - 24 cm; Flow - 0.358 m/s; SD - 0.403. Flow was subsequently measured using the floating stick method due to the SD of the flow meter consistently remaining above 0.2. Flow using floating stick method: Transit Length - 3 m; Transit Time 1 - 19.45 s; Transit Time 2 - 23.22 s; Transit Time 3 - 23.31 s. Calculated flow rate – 0.14 m/s. Shore cannot be accessed due to MOD area.
3	04/11/2014	9:51	NG 87485 88530	187485	888531			Scottish Water Structure on shore with houses behind.
4	04/11/2014	9:56	NG 87398 88407	187398	888408			Seven hooded crows on shore. Ten buoys out at sea.
5	04/11/2014	10:00	NG 87453 88504	187454	888504			Metal pipe just visible in ground. Cannot see if flowing or not.
6	04/11/2014	10:01	NG 87438 88516	187438	888516	Figure 5	LESW1	Planned seawater sample below Scottish Water Community structure.
7	04/11/2014	10:07	NG 87449 88560	187450	888560	Figure 6	LEFW2	Unplanned freshwater sample from pipe. Sample associated with waypoint 8.
8	04/11/2014	10:07	NG 87449 88560	187450	888560	Figure 6		Freshwater sample taken from pipe on shore. No flow measured as pipe only dripping. Pipe diameter 100 mm. Houses behind.
9	04/11/2014	10:13	NG 87471 88551	187471	888551			Drainage pipe not sampled. Run-off from road above.
10	04/11/2014	10:25	NG 87357 88981	187357	888982	Figure 7	LEFW3	Planned freshwater sample from Allt Beithe river. Sample associated with waypoint 11.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
11	04/11/2014	10:25	NG 87357 88981	187357	888981	Figure 7		Freshwater sample taken from large river running next to hotel. Public toilets next to river as well as houses. Width - 11 m 43 cm; Depth 1 - 30 cm; Flow 1 - 0.467 m/s; SD 1 - 0.026. Depth 2 - 28 cm; Flow 2 - 0.313 m/s; SD 3 - 0.054.
12	04/11/2014	10:46	NG 86761 88890	186761	888891	Figure 8	LESW2	Planned seawater sample from pier. Three fishing boats in water.
13	04/11/2014	10:48	NG 86761 88888	186762	888889			Two boats on shore. Ten seagulls.
14	04/11/2014	11:04	NG 86430 89353	186430	889353			One common gull, nineteen cormorants and one lesser black-backed gull on concrete structure out at sea. Approximately forty starlings in garden on shore.
15	04/11/2014	11:31	NG 86508 89801	186508	889802	Figure 9	LEFW4	Planned freshwater sample from Allt an Raoin Chiuaidh watercourse. Sample associated with waypoint 16.
16	04/11/2014	11:31	NG 86508 89801	186509	889801	Figure 9		Width - 6 m 62 cm; Depth 1 - 15 cm; Flow 1 - 0.564 m/s; SD 1 - 0.032. Depth 2 - 15 cm; Flow 2 - 0.560 m/s; SD - 0.044. House next to river. River runs under road onto shore.
17	04/11/2014	11:51	NG 86458 89732	186458	889732		LESF1	Shore mussel sample near to river.
18	04/11/2014	11:58	NG 86483 89819	186483	889820			Metal pipe leading onto shore. No flow. House behind.
19	04/11/2014	12:22	NG 85427 90489	185427	890489		LESW3	Planned seawater sample.
20	04/11/2014	12:23	NG 85425 90489	185426	890490			Marine Harvest station on shore next to pier. Two boats on shore. One dredger on shore. Three buoys out at sea.
21	04/11/2014	12:31	NG 85343 90641	185343	890642		LEFW5	Planned freshwater sample from Allt Bhruachan Ruadha watercourse. Sample associated with waypoint 22.
22	04/11/2014	12:31	NG 85343 90641	185344	890642			Width - 2 m 28 cm; Depth - 17 cm; Flow - 0.583 m/s; SD - 0.009. Watercourse running onto shore with houses behind. One heron on shore.
23	04/11/2014	12:40	NG 85205 90788	185205	890788		LEFW6	Planned freshwater sample from Allt Beinn Dearg watercourse. Sample associated with waypoint 24.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
24	04/11/2014	12:40	NG 85205 90788	185205	890788			Width - 1m 91 cm; Depth - 17 cm; Flow - 0.372 m/s; SD - 0.045. Watercourse running onto shore with houses behind. Six mallard ducks, one heron and fourteen common gulls on rocks and water.
25	04/11/2014	12:51	NG 85457 90566	185457	890566			Scottish Water Community structure.
26	04/11/2014	14:10	NG 84072 91116	184073	891117	Figure 10		Most northerly part of shoreline walk. Three houses. Steep rocky cliffs so cannot access all of shoreline. One common gull overhead.
27	04/11/2014	14:23	NG 84166 90951	184167	890952		LESW4	Planned seawater sample. Two lesser black-backed gulls on water.
28	04/11/2014	14:38	NG 84403 91080	184403	891081	Figure 11		Three large pipes leading into sea from disused marine research centre. Four greylag geese overhead.
29	04/11/2014	14:43	NG 84485 91067	184486	891067			Broken clay pipe, flowing. Not sampled as only disused campsite on shore above.
30	04/11/2014	14:46	NG 84578 91027	184578	891027	Figure 12	LEFW7	Planned freshwater sample from Allt na Faiche watercourse. Sample associated with waypoint 31.
31	04/11/2014	14:46	NG 84578 91027	184578	891027	Figure 12		Watercourse running onto shore. Width - 1 m 22 cm; Depth - 21 cm; Flow - 0.759 m/s; SD - 0.032. Two common gulls overhead. Five static caravans in field behind.
32	04/11/2014	15:16	NG 85171 90808	185171	890809			End of shoreline walk next to river sampled previously at waypoint 23.
33	04/11/2014	15:26	NG 84895 90982	184895	890983			Eighteen sheep in field above shore.
34	04/11/2014	16:13	NG 85658 80988	185658	880989			Poolewe hotel. Concrete slab with manhole covers on shore below.
35	04/11/2014	16:20	NG 85458 81063	185458	881064			Possible Poolewe pumping station structure on shore.
36	04/11/2014	16:41	NG 85806 80793	185806	880794	Figure 13	LEFW8	River Ewe freshwater sample taken from below pumping station. Measurements were not required as per the sampling plan.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
37	05/11/2014	9:58	NG 85248 89357	185249	889358			CTD cast from NE corner pf production area.
38	05/11/2014	9:58	NG 85248 89358	185248	889358		LESW5	Planned seawater sample.
39	05/11/2014	10:01	NG 85218 89380	185218	889380	Figure 14		North east corner of several fishery area. Three long lines observed.
40	05/11/2014	10:08	NG 85908 88583	185908	888583			CTD cast from SE corner of several fishery area.
41	05/11/2014	10:08	NG 85910 88579	185911	888580		LESW6	Planned seawater sample.
42	05/11/2014	10:09	NG 85912 88577	185912	888578			One common gull overhead. Three common gulls on shore. Three other fishing boats on water. Three small boats on water.
43	05/11/2014	10:15	NG 85636 88815	185636	888815		LESF2	Mussel sample from RMP.
44	05/11/2014	10:36	NG 84930 89146	184931	889146			Start of Isle of Ewe shoreline walk. One boat observed at sea off Isle of Ewe. According to Ms Grant, there is a heron colony in trees on the shore of the Isle of Ewe just north of waypoint 44. Four herons observed on rocks on shore.
45	05/11/2014	10:50	NG 85073 88959	185074	888959		LEFW9	Planned freshwater sample from unnamed watercourse. Sample associated with waypoint 46.
46	05/11/2014	10:50	NG 85073 88958	185073	888959			Small river running onto shore with moorland behind. Width - 28 cm; Depth - 14 cm; Flow - 0.138 m/s; SD - 0.004.
47	05/11/2014	11:13	NG 85381 88763	185382	888763		LEFW10	Planned freshwater sample from unnamed watercourse. Sample associated with waypoint 48. …
48	05/11/2014	11:13	NG 85381 88763	185382	888763			River running onto shore. One seagull. Width - 1 m 62 cm; Depth - 17 cm; Flow - 0.425 m/s; SD - 0.019.
49	05/11/2014	11:30	NG 85529 88588	185529	888589			Farm house with barn. No animals observed.
50	05/11/2014	11:33	NG 85642 88536	185643	888536			End of shoreline walk on Isle of Ewe.
51	05/11/2014	12:42	NG 87118 89112	187118	889112			Metal pipe, no flow. Houses behind with one horse in field next to road.
52	05/11/2014	12:45	NG 87202 89059	187202	889059	Figure 15		Metal pipe, no flow.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
53	05/11/2014	12:46	NG 87213 89052	187213	889053			Plastic pipe, no flow.
54	05/11/2014	13:00	NG 87241 88936	187241	888936		LESF3	Shore mussels from next to river near hotel.

Photographs referenced in the table can be found attached as Figures 4 – 15.

Sampling

Seawater and freshwater samples were collected at the sites marked in Figure 3. All planned freshwater samples and seawater samples were obtained. One extra freshwater sample, LEFW2 was also taken from a pipe at waypoint 7.

Shore mussel samples were obtained at waypoints 17 and 54 and a further mussel sample was collected from the RMP at waypoint 43.

All the samples were transferred to a Biotherm 30 box with ice packs and posted to Glasgow Scientific Services (GSS) for *E. coli* analysis. Freshwater samples LEFW9 and LEFW10, mussel samples LESF2 and LESF3 and seawater samples LESW5 and LESW 6 were received by GSS within 24 hours of collection. Freshwater samples LEFW1 to LEFW8, mussel sample LESF1 and seawater samples LESW1 to LESW4 were received by GSS within 48 hours of collection. (A sample submission extension of 48 hours was granted for all samples due to the remote location of the survey). The sample temperature on arrival at GSS for all samples was 4.0°C.

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

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

Table 2. Water Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (cfu/100ml)	Salinity (ppt)
1	04/11/2014	LEFW1	NG 87788 88097	Freshwater	20	
2	04/11/2014	LESW1	NG 87438 88516	Seawater	100	33.60
3	04/11/2014	LEFW2	NG 87449 88560	Freshwater	<1000	
4	04/11/2014	LEFW3	NG 87357 88981	Freshwater	110	
5	04/11/2014	LESW2	NG 86761 88890	Seawater	66	31.80
6	04/11/2014	LEFW4	NG 86508 89801	Freshwater	410	
7	04/11/2014	LESW3	NG 85427 90489	Seawater	3	34.69
8	04/11/2014	LEFW5	NG 85343 90641	Freshwater	230	
9	04/11/2014	LEFW6	NG 85205 90788	Freshwater	90	
10	04/11/2014	LESW4	NG 84166 90951	Seawater	3	34.51
11	04/11/2014	LEFW7	NG 84578 91027	Freshwater	210	
12	04/11/2014	LEFW8	NG 85806 80793	Freshwater	<10	
13	05/11/2014	LESW5	NG 85248 89358	Seawater	3	26.74
14	05/11/2014	LESW6	NG 85910 88579	Seawater	12	10.88
15	05/11/2014	LEFW9	NG 85073 88959	Freshwater	<10	
16	05/11/2014	LEFW10	NG 85381 88763	Freshwater	40	

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	Sample depth (m)	E. coli (MPN/100g)
1	04/11/2014	LESF1	NG 86458 89732	Mussel	-	18
2	05/11/2014	LESF2	NG 85636 88815	Mussel	-	<18
3	05/11/2014	LESF3	NG 87241 88936	Mussel	-	18

Salinity Profiles

Two CTD profiles were taken at locations detailed in Figure 3. The gathered data will be sent to Cefas as agreed previously on a separate Excel sheet.

6. SEPA Discharge Consents

Licence No.	NGR	Discharge Type	Discharges to	MDF (m3/d)	PE	Overflow M3/day
CAR/L/1001810	NG 87000 86200	Fish Farm Marine Cage				
CAR/L/1001814	NG 83600 83400	Fish Farm Marine Cage				
CAR/L/1001924	NG 8677 8906	Sewage (Public) Primary	Loch Ewe			
CAR/L/1002124	NG 85922 81723	Sewage (Public) Primary	Loch Ewe			
CAR/L/1002135	NG 85850 81150	Sewage (Public) Emergency Overflow (EO)				
CAR/L/1002337	NG 82420 84514	Other Effluent Potable Water Treatment and Supply				
CAR/L/1002963	NG 83680 88560	Fish Farm Marine Cage				
CAR/L/1010001	NG 84420 81420					
CAR/L/1012609	NG 84450 90890	Abstraction Fish Production				
CAR/L/1012609	NG 85027 92335	Abstraction Fish Production				
CAR/L/1031729	NG 83690 92330	Sewage (Public) Primary	Loch Ewe	1512	931	
CAR/L/1031729	NG 87420 88520	Sewage (Public) Combined Sewer Overflow (CSO)				10.7
CAR/L/1031729	NG 87420 88520	Sewage (Public) Emergency Overflow (EO)				
CAR/L/1031729	NG 87150 88930	Sewage (Public) Combined Sewer Overflow (CSO)				6
CAR/L/1031729	NG 87150 88930	Sewage (Public) Emergency Overflow (EO)				
CAR/L/1031729	NG 86840 88910	Sewage (Public) Combined Sewer Overflow (CSO)				6.9
CAR/L/1031729	NG 86840 88910	Sewage (Public) Emergency Overflow (EO)				12
CAR/L/1031729	NG 86190 90130	Sewage (Public) Combined Sewer Overflow (CSO)				
CAR/L/1031729	NG 86190 90130	Sewage (Public) Emergency Overflow (EO)				
CAR/L/1031729	NG 85480 90450	Sewage (Public) Combined Sewer Overflow (CSO)				12.71
CAR/L/1031729	NG 85480 90450	Sewage (Public) Emergency Overflow (EO)				
CAR/L/1031729	NG 85090 90710	Sewage (Public) Combined Sewer Overflow (CSO)				13.61
CAR/L/1031729	NG 85090 90710	Sewage (Public) Emergency Overflow (EO)				
CAR/L/1031729	NG 84850 90800	Sewage (Public) Combined Sewer Overflow (CSO)				14.8
CAR/L/1031729	NG 84850 90800	Sewage (Public) Emergency Overflow (EO)				17.49
CAR/L/1031729	NG 84030 91440	Sewage (Public) Combined Sewer Overflow (CSO)				
CAR/L/1031729	NG 84030 91440	Sewage (Public) Emergency Overflow (EO)				
CAR/L/1040948	NG 85470 81250	Sewage (Public) Primary	Loch Ewe		749	
CAR/L/1092167	NG 86021 81422	Sewage (Public) Emergency Overflow (EO)				
CAR/L/1092167	NG 85760 81040	Sewage (Public) Emergency Overflow (EO)				
CAR/L/1092167	NG 85760 81039	Sewage (Public) Combined Sewer Overflow (CSO)				
CAR/L/1092167	NG 8585 8085	Sewage (Public) Emergency Overflow (EO)				
CAR/L/1092167	NG 85812 80781	Sewage (Public) Emergency Overflow (EO)				
CAR/R/1007483	NG 87500 83480	Sheep Dip onto Land				
CAR/R/1007500	NG 81370 88920	Sheep Dip onto Land				
CAR/R/1007704	NG 85980 90860	Sheep Dip onto Land				
CAR/R/1010626	NG 88550 88990	Sewage (Private) Primary	Soakaway		5	
CAR/R/1012178	NG 86141 80170	Sewage (Private) Primary	River Ewe		7	
CAR/R/1012180	NG 86085 79893	Sewage (Private) Primary	River Ewe		5	
CAR/R/1014823	NG 84930 91470	Sewage (Private) Primary	Land		5	

CAR/R/1015220	NG 82339 85600	Sewage (Private) Primary	Loch Ewe		6	
CAR/R/1016413	NG 87250 89030	Sewage (Private) Untreated	Loch Ewe		5	
CAR/R/1016414	NG 87248 89033	Sewage (Private) Untreated	Loch Ewe		5	
CAR/R/1016989	NG 85935 80081	Sewage (Private) Primary	Land		5	
CAR/R/1017792	NG 87449 88968	Sewage (Private) Primary	Allt Beithe		15	
CAR/R/1018221	NG 84106 90929	Sewage (Private) Primary	Loch Ewe		6	
CAR/R/1018263	NG 85390 90650	Sewage (Private) Primary	Land		5	
CAR/R/1018367	NG 87475 88942	Sewage (Private) Primary	Land		7	
CAR/R/1019788	NG 82420 87560	Sewage (Private) Primary	Land		5	
CAR/R/1019861	NG 80938 91257	Sewage (Private) Secondary	UN/WC		5	
CAR/R/1020156	NG 84900 91670	Sewage (Private) Primary	Land		6	
CAR/R/1021277	NG 85900 90450	Sewage (Private) Primary	Soakaway		5	
CAR/R/1021628	NG 87180 89560	Sewage (Private) Primary	Soakaway		5	
CAR/R/1027896	NG 87340 89819	Sewage (Private) Primary	Soakaway		5	
CAR/R/1028405	NG 87150 89430	Sewage (Private) Primary	Soakaway		10	
CAR/R/1030364	NG 86590 90330	Sewage (Private) Primary	Soakaway		6	
CAR/R/1030685	NG 82060 85830	Sewage (Private) Primary	Soakaway		6	
CAR/R/1031092	NG 82030 87240	Sewage (Private) Primary	Soakaway		6	
CAR/R/1031100	NG 83970 92170	Industrial or Commercial: Process Water				
CAR/R/1033104	NG 86200 81640	Sewage (Private) Primary	Loch Ewe		15	
CAR/R/1033126	NG 86200 81630	Sewage (Private) Primary	Loch Ewe		15	
CAR/R/1033138	NG 85890 81790	Sewage (Private) Primary	Loch Ewe		15	
CAR/R/1033517	NG 85425 81094	Industrial or Commercial: Process Water				
CAR/R/1033898	NG 87441 88969	Sewage (Private) Primary	Allt Beithe		25	
CAR/R/1035839	NG 85870 80130	Sewage (Private) Primary	Soakaway		5	
CAR/R/1045066	NG 81350 91560	Sewage (Private) Primary	Loch Ewe		6	
CAR/R/1045071	NG 80916 89718	Sewage (Private) Primary	Allt Eion Thomais		6	
CAR/R/1045142	NG 85829 90634	Sewage (Private) Primary	Soakaway		5	
CAR/R/1045219	NG 84715 91406	Sewage (Private) Primary	Soakaway		7	
CAR/R/1045598	NG 87550 88940	Sewage (Private) Primary	Land		5	
CAR/R/1046553	NG 84335 91117	Sewage (Private) Primary	Soakaway		6	
CAR/R/1047533	NG 88955 89380	Sewage (Private) Primary	Soakaway		6	
CAR/R/1048260	NG 87416 88503	Sewage (Private) Primary	Loch Ewe		5	
CAR/R/1048681	NG 85875 80180	Sewage (Private) Primary	Soakaway		5	
CAR/R/1048813	NG 84870 91110	Sewage (Private) Primary	Loch Ewe		5	
CAR/R/1049697	NG 82140 84809	Sewage (Private) Primary	Loch Ewe		5	
CAR/R/1050074	NG 87800 88820	Sewage (Private) Primary	Soakaway		5	
CAR/R/1050136	NG 87980 88810	Sewage (Private) Secondary	Land		5	
CAR/R/1050485	NG 80910 90890	Sewage (Private) Primary	Soakaway		5	
CAR/R/1052477	NG 87100 89780	Sewage (Private) Primary	Land		6	
CAR/R/1053315	NG 82330 86990	Sewage (Private) Primary	Soakaway		5	
CAR/R/1053531	NG 86910 89203	Sewage (Private) Primary	Loch Ewe		5	
CAR/R/1053652	NG 81460 86020	Sewage (Private) Primary	Soakaway		5	
CAR/R/1054007	NG 81920 85060	Sewage (Private) Primary	Soakaway		5	

CAR/R/1054702	NG 80820 90430	Sewage (Private) Primary	Soakaway		5	
CAR/R/1055125	NG 85540 90840	Sewage (Private) Primary	Soakaway		5	
CAR/R/1055814	NG 85905 90417	Sewage (Private) Primary	Soakaway		5	
CAR/R/1057361	NG 82160 84760	Sewage (Private) Primary	Loch Ewe		6	
CAR/R/1058080	NG 85821 80524	Sewage (Private) Primary	Soakaway		36	
CAR/R/1058882	NG 87100 89724	Sewage (Private) Primary	UN/WC		5	
CAR/R/1059001	NG 86330 90340	Sewage (Private) Primary	Land		6	
CAR/R/1065543	NG 82050 86150	Sewage (Private) Primary	Soakaway		5	
CAR/R/1065648	NG 87897 88939	Sewage (Private) Primary	Allt Beithe		5	
CAR/R/1065678	NG 85307 91083	Sewage (Private) Primary	Loch Ewe		5	
CAR/R/1065855	NG 85420 90600	Sewage (Private) Primary	Soakaway		5	
CAR/R/1066543	NG 82510 86831	Sewage (Private) Primary	Soakaway		5	
CAR/R/1067240	NG 87130 89386	Sewage (Private) Primary	Soakaway		5	
CAR/R/1067250	NG 80870 90860	Sewage (Private) Primary	Land		5	
CAR/R/1067968	NG 86960 89190	Sewage (Private) Primary	Loch Ewe		5	
CAR/R/1068061	NG 87383 88496	Sewage (Private) Primary	Loch Ewe		5	
CAR/R/1068297	NG 82100 86500	Sewage (Private) Primary	Land		5	
CAR/R/1068501	NG 82070 86570	Sewage (Private) Primary	Soakaway		5	
CAR/R/1069077	NG 87474 88974	Sewage (Private) Primary	Allt Beithe		5	
CAR/R/1069340	NG 84380 90980	Sewage (Private) Primary	Loch Ewe		5	
CAR/R/1071435	NG 86968 89185	Sewage (Private) Primary	Loch Ewe		5	
CAR/R/1071857	NG 84502 91696	Sewage (Private) Primary	Soakaway		5	
CAR/R/1072303	NG 80806 90633	Sewage (Private) Primary	Allt na Glaic		5	
CAR/R/1075916	NG 84690 91025	Sewage (Private) Primary	Soakaway		7	
CAR/R/1076014	NG 84034 91373	Sewage (Private) Primary	Loch Ewe			
CAR/R/1076051	NG 87137 89146	Sewage (Private) Primary	Loch Ewe		15	
CAR/R/1076171	NG 84769 90926	Sewage (Private) Primary	Soakaway		6	
CAR/R/1076177	NG 84160 91420	Sewage (Private) Primary	Camas nan Dornag		5	
CAR/R/1076182	NG 84715 91165	Sewage (Private) Primary	Allt na Faiche		5	
CAR/R/1076342	NG 85449 90943	Sewage (Private) Primary	Soakaway		5	
CAR/R/1076347	NG 81861 87867	Sewage (Private) Primary	Soakaway		5	
CAR/R/1076572	NG 85428 90554	Sewage (Private) Primary	Loch Ewe		15	
CAR/R/1076815	NG 81075 91620	Sewage (Private) Primary	UN/WC		5	
CAR/R/1077402	NG 81840 87760	Sewage (Private) Primary	Soakaway		50	
CAR/R/1077440	NG 84500 91340	Sewage (Private) Primary	Soakaway		5	
CAR/R/1077442	NG 84460 91384	Sewage (Private) Primary	Soakaway		5	
CAR/R/1077444	NG 84443 91331	Sewage (Private) Primary	Soakaway		5	
CAR/R/1077553	NG 84668 91871	Sewage (Private) Primary	Land		5	
CAR/R/1078181	NG 82199 86835	Sewage (Private) Primary	Soakaway		7	
CAR/R/1078375	NG 84421 91420	Sewage (Private) Primary	Soakaway		5	
CAR/R/1078726	NG 82690 83370	Sewage (Private) Secondary	Soakaway		6	
CAR/R/1078729	NG 82678 83200	Sewage (Private) Primary	Soakaway		5	
CAR/R/1079394	NG 81535 85698	Sewage (Private) Secondary	U/T of alt na Leth-chreige		8	
CAR/R/1079924	NG 82502 83499	Sewage (Private) Secondary	Allt Donn		6	

CAR/R/1080766	NG 85030 91350	Sewage (Private) Primary	Soakaway		5	
CAR/R/1084776	NG 82080 86720	Sewage (Private) Primary	Soakaway		5	
CAR/R/1092711	NG 82200 86000	Sewage (Private) Secondary	Soakaway		6	
CAR/R/1093463	NG 87764 83491	Sewage (Private) Primary	U/T of Loch na Dailthean		15	
CAR/R/1093466	NG 87691 83487	Sewage (Private) Primary	U/T of Loch na Dailthean		9	
CAR/R/1093468	NG 87410 83670	Sewage (Private) Primary	Loch Thurnaig		10	
CAR/R/1095264	NG 82770 83160	Sewage (Private) Primary	Seasgach Burn		8	
CAR/R/1100108	NG 85649 80593	Sewage (Private) Primary	Soakaway		5	
CAR/R/1104886	NG 82700 87300	Sewage (Private) Primary	Coast		6	
CAR/R/1106233	NG 82260 87110	Sewage (Private) Primary	Soakaway		6	
CAR/R/1111686	NG 80482 90504	Sewage (Private) Secondary	Allt na Glaic Cuilceich		5	
CAR/R/1120484	NG 80635 90565	Sewage (Private) Primary	Allt na Glaic Cuilceich		6	
CAR/S/1016031	NG 88080 88380	Sheep Dip onto Land				
CAR/S/1016031	NG 87540 83620	Sheep Dip onto Land				
CAR/S/1016031	NG 87520 83540	Sheep Dip onto Land				
CAR/S/1016031	NG 87500 83480	Sheep Dip onto Land				
CAR/S/1016627	NG 81370 88920	Sheep Dip onto Land				
CAR/S/1016627	NG 81350 88930	Sheep Dip onto Land				
CAR/S/1016627	NG 81120 90660	Sheep Dip onto Land				
CAR/S/1016627	NG 80860 90550	Sheep Dip onto Land				
CAR/S/1016627	NG 80880 90600	Sheep Dip onto Land				
CAR/S/1016627	NG 81330 91650	Sheep Dip onto Land				
CAR/S/1116459	NG 85980 90860	Sheep Dip onto Land				
CAR/S/1116459	NG 85950 90880	Sheep Dip onto Land				
CAR/S/1116459	NG 85920 90900	Sheep Dip onto Land				

LS=Land/Soakaway, SW= Seawater Body, FW= Freshwater Body, PE= Population Equivalent, - = Not applicable

7. Loch Ewe CTD data

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

Figure A6.1 Location of CTD cast

CAST 1

Data Header

% Device	10G100653
% File name	10G100653_20141105_095905
% Cast time (local)	05/11/2014 09:59
% Sample type	Cast
% Cast data	Processed
% Location source	GPS
% Start latitude	57.8420504
% Start longitude	-5.6201312
% Start GPS horizontal error(Meter)	26.12000084
% Start GPS vertical error(Meter)	31.70000076
% Start GPS number of satellites	4
% Cast duration (Seconds)	77.2
% Samples per second	5
Calibration Date	March 2013
Calibration offset for Temperature	-0.033
Calibration offset for Salinity	0.029

CTD data (calibration offsets applied)

Depth (Meter)	Temperature (Celsius)	Salinity (Practical Salinity Scale)
0.149450352	10.05286503	29.06638656
0.448293869	10.18568889	29.42878508
0.74704036	10.36109328	30.03489843
1.045685546	10.55048703	30.39356726
1.344215772	10.76379631	31.13085548
1.642599614	10.89489548	31.75619608
1.940881544	10.96576946	32.071867
2.239109781	10.98337441	32.24706063
2.537310339	11.0558907	32.33367157
2.835491587	11.10143984	32.4413753
3.133658145	11.13945943	32.47948646
3.431817279	11.14654697	32.51427213
3.729966305	11.16611366	32.57192849
4.028087828	11.22621313	32.77267821
4.326174525	11.27353519	32.90155627
4.624233529	11.32080253	33.0364847
4.922282888	11.36166106	33.00430917
5.220333801	11.36982165	33.03114719
5.518377482	11.38471029	33.07068403
5.816413138	11.41266834	33.10916969
6.114444753	11.43455249	33.11509124
6.412470615	11.45919647	33.16798887
6.710487786	11.48383963	33.20057872
7.008496967	11.49143103	33.24329942
7.306497997	11.50821014	33.27548534
7.604487325	11.50773396	33.34776503

7.831880845	11.5300371	33.40221852

CAST 2

Data Header

% Device	10G100653
% File name	10G100653_20141105_101105
% Cast time (local)	05/11/2014 10:11
% Sample type	Cast
% Cast data	Processed
% Location source	GPS
% Start latitude	57.8351847
% Start longitude	-5.6079838
% Start GPS horizontal error(Meter)	4.369999886
% Start GPS vertical error(Meter)	5.699999809
% Start GPS number of satellites	5
% Cast duration (Seconds)	63.4
% Samples per second	5
Calibration Date	March 2013
Calibration offset for Temperature	-0.033
Calibration offset for Salinity	0.029

CTD data (calibration offsets applied)

Depth (Meter)	Temperature (Celsius)	Salinity (Practical Salinity Scale)
0.150221575	9.516920435	22.22353598
0.449838835	10.38940861	29.46436694
0.748545055	10.46709769	30.42608261
1.04714463	10.46411252	30.41533383
1.345726393	10.51093516	30.58925259
1.644286225	10.61493803	30.63780367
1.942775492	10.70597198	31.25023069
2.241172581	10.81157032	31.49027328
2.539513132	10.9325963	31.79608062
2.837782249	10.99333746	32.15832029
3.136003571	11.06504441	32.24491118
3.434195382	11.13370923	32.44785051
3.732349666	11.2146009	32.60763484
4.030446628	11.33590501	32.99822261
4.328479211	11.46248648	33.23163125
4.626479516	11.53079747	33.32650226
4.924470311	11.57684476	33.33975671
5.222458148	11.60041746	33.36615062
5.520437543	11.61258534	33.42000129
5.818406182	11.63763359	33.46725136
6.116362524	11.65781542	33.53669307
6.414305402	11.68098648	33.59386838
6.712236773	11.71091113	33.64831302
7.010159455	11.7230495	33.67793248
7.30807852	11.72693718	33.68121783

7.605996276	11.73041558	33.68832815
8.040675763	11.72169369	33.68880244