Scottish Sanitary Survey Report

Sanitary Survey Report
Inner Loch Torridon
RC-090
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1.0	28/05/2014	ii,iii,1, 21, 55, 56	Change RMP to intertidal shore to allow regular sampling per feedback from sampling officer. Other minor typographical changes in line with consultation responses.

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Partner Organisations

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

Table of Contents

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I. Executive Summary

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

The purpose of the sanitary survey is to demonstrate compliance with the requirements stated in Annex II (Chapter II Paragraph 6) of Regulation (EC) 854/2004. The sanitary survey results in recommendations on the location of RMPs, the frequency of sampling for microbiological monitoring, and the boundaries of the production areas deemed to be represented by the RMPs. A sanitary survey was undertaken on the classified mussel fishery at Inner Loch Torridon on the basis recommended in the European Union Reference Laboratory publication: “Microbiological Monitoring of Bivalve Mollusc Harvesting Area Guide to Good Practice: Technical Application” (http://www.crlcefas.org/gpg.asp). The area was selected for survey at this time based on a risk-based ranking amongst those Scottish production areas that had yet to receive a survey.

The Inner Loch Torridon classified production area lies within Upper Loch Torridon, on the west coast of Scotland, within the Ross and Cromarty district of the Highland Council.

At the time of survey, there were three active long line mussel farms present in three small embayments along the south shore of the loch.

The principal sources of contamination to the mussel fishery lie around the head of the loch, where there are community and private septic tanks, as well as the main watercourse inputs to the area and the main area of agricultural use. In addition, there were smaller sources along the north shore of the loch and also west of Ob Gorm Beag.

Contaminants are estimated to be carried in the order of 1.3 km by tidal flow, though flows may be enhanced when wind is from the east and reduced when flows are from the west.

It is recommended that the production area be curtailed to encompass the area in use as a mussel fishery and to exclude identified point sources of faecal contamination. It is recommended that the RMP be moved to the southeast corner of the Dubh Aird site, where it will better reflect human and agricultural sources of contamination arising around the head of the loch.

II. Sampling Plan

Production Area	Inner Loch Torridon
Site Name	Dubh Aird
SIN	RC-090-1616-08
Species	Common mussels
Type of Fishery	Long line aquaculture
NGR of RMP	NG 8752 5502
East	187520
North	855020
Tolerance (m)	75
Depth (m)	Not applicable
Method of Sampling	Hand
Frequency of Sampling	Monthly
Local Authority	Highland Council – Ross & Cromarty
Authorised Sampler(s)	Hamish Spence Bill Steven
Local Authority Liaison Officer	Alan Yates
Production Area Boundaries	The area within lines drawn between NG 8542 5501 and NG 8542 5600 and between NG 8542 5600 and NG 8796 5600 and between NG 8796 5600 and NG 8796 5489 extending to mean high water springs (MHWS)

III. Report

1. General Description

Upper Loch Torridon is a sea loch on the west coast of Scotland, within the Ross and Cromarty district of the Highland Council. It forms the inner part of a series of lochs, flowing through Loch Shieldaig to Loch Torridon, into the Minch. Upper Loch Torridon, has a westerly aspect and is sheltered by a narrow strait connecting it to Loch Torridon, which opens to the northwest.

Upper Loch Torridon is approximately 10 km long and is approximately 2.5 km wide along most of its length. The maximum chart depth is 73 m; however Gillibrand and Amumdrud (2007) state that the maximum depth for the loch is 93 m.

The area surrounding Upper Loch Torridon is sparsely inhabited, with two main settlements: Inverallign on the north shore and Torridon, at the head of the loch, a third settlement of Shieldaig lies just west of Upper Loch Torridon in Loch Shieldaig.

Although the water body is called Upper Loch Torridon, the classified shellfish production area is identified as Inner Loch Torridon, and these terms will be used accordingly throughout the report.

This sanitary survey was undertaken on the Inner Loch Torridon production area on the basis recommended in the European Union Reference Laboratory publication: "Microbiological Monitoring of Bivalve Mollusc Harvesting Area Guide to Good Practice: Technical Application" (http://www.crlcefas.org/gpg.asp). This production area was selected for survey at this time based on a risk-based ranking of the area amongst those in Scotland that have yet to receive sanitary surveys. The locations of Loch Torridon and Upper Loch Torridon are shown in Figure 1.1.

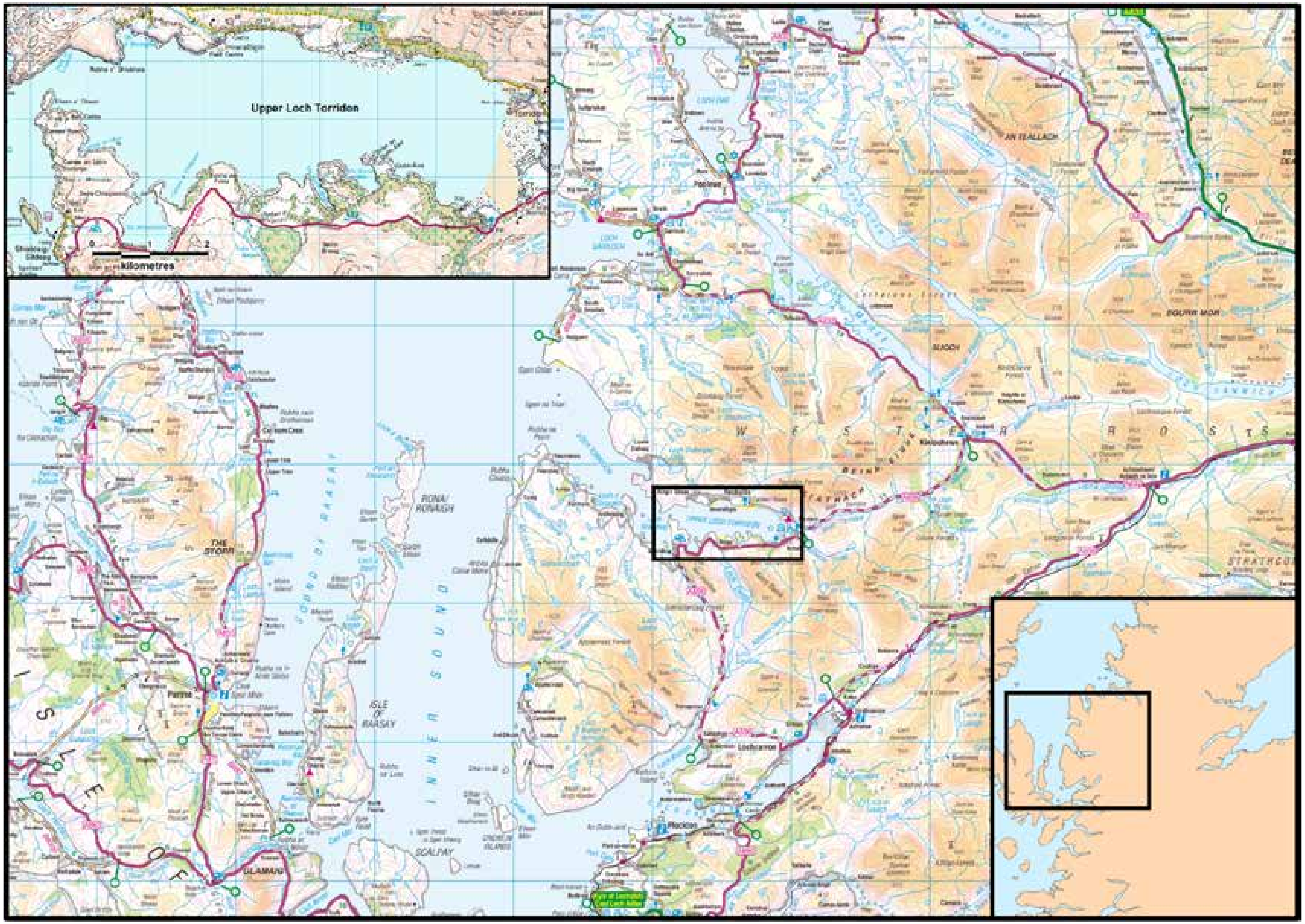

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Figure 1.1 Location of Upper Loch Torridon

2. Fishery

The Inner Loch Torridon fishery consists of common mussel (*Mytilus edulis*) farms, which have been classified for production since 2001. Details of the sites are presented in Table 2.1.

Table 2.1 Inner Loch Torridon shellfish farms

Production area	Site	SIN	Species	RMP
Inner Loch Torridon	Ob Gorm Beag	RC-090-1617-08	Common mussels	
Inner Loch Torridon	Ob Gorm Mor	RC-090-245-08	Common mussels	NG 8697 5502
Inner Loch Torridon	Dubh Aird	RC-090-1616-08	Common mussels	

Mussels are grown on droppers suspended from long-lines set in three small inlets along the south shore of the loch. Two sites identified in the 2013 classification report, Camas a Chlarsair and Rubha na Feola, were reported to be defunct.

The production area boundaries are defined as the area within lines drawn between NG 8059 5655 and NG 8110 5600 extending to mean high water springs (MHWS). The boundaries incorporate the entire area of Upper Loch Torridon.

At the time of the shoreline survey there were three sets of lines observed at each of the three sites. No dropper length was noted. The Ob Gorm Beag and Ob Gorm Mor sites were observed to be in a poor state of repair during the shoreline survey and the local sampling officer indicated that they had not been worked in some time. Mature stock was observed on all three sites.

The fishery locations described in the shoreline survey report are plotted in Figure 2.1.

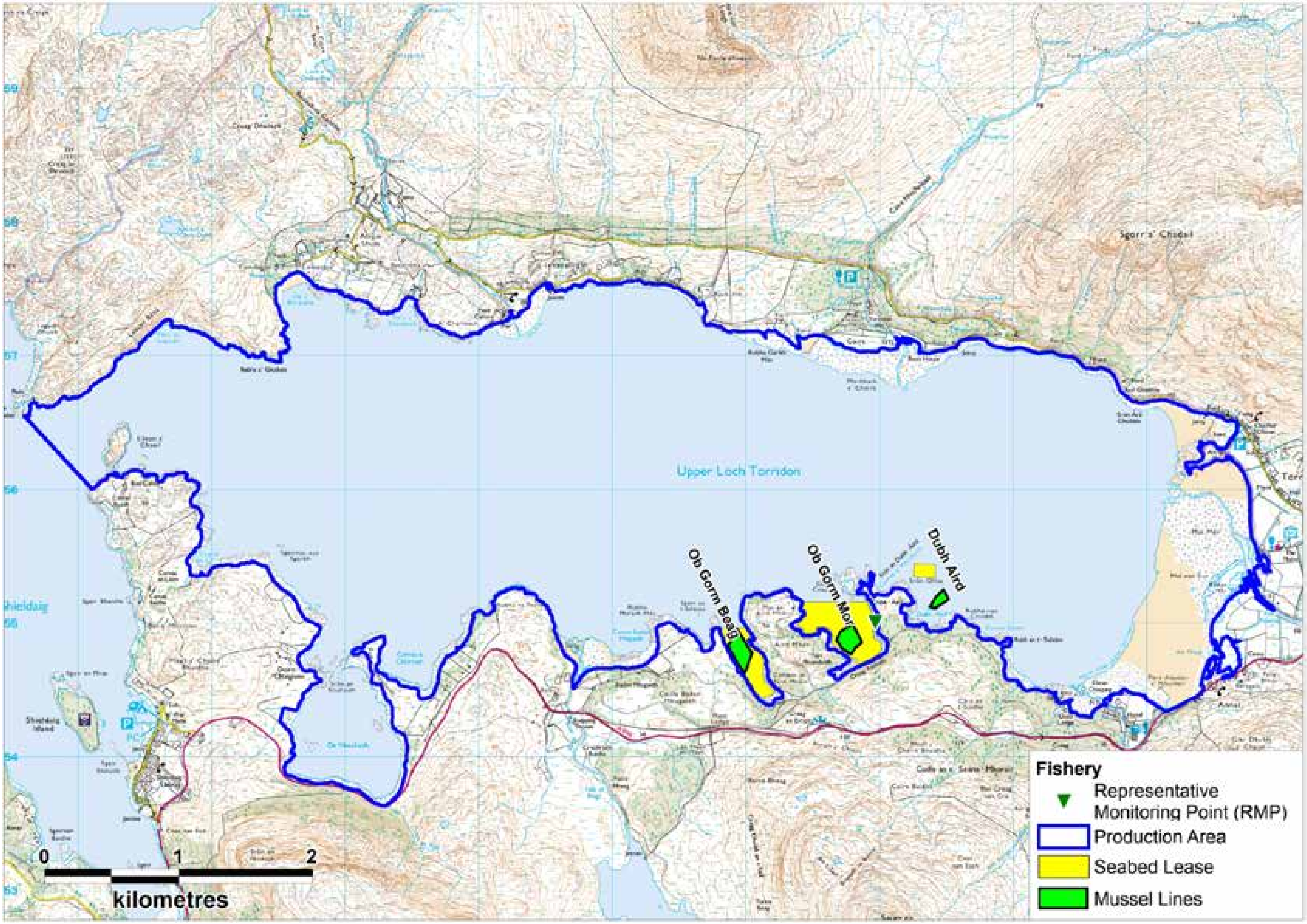

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Figure 2.1 Inner Loch Torridon Area Fishery

3. Human Population

Data from the 2011 population census was obtained for the area around Inner Loch Torridon from the General Register Office for Scotland. The census output areas are shown mapped by population density in Figure 3.1. Overall population density for the area is low (<2 people per sq km), with the majority of the resident population located around the main settlements and along the roads skirting the loch.

The main settlements are Torridon and Inveralligin. Torridon is located at the eastern end of the loch and has a primary school, a community centre with sports, conference and exhibition facilities, a youth hostel and caravan and camping site. Inveralligin is located on the northern shore of the loch, approximately 3 km northwest of the mussel farms. During the shoreline survey, a single dwelling was observed on the shore west of the Ob Gorm Mor fishery.

Approximately 1.5 km south east of the fishery there is a cluster of various tourist accommodation including a hotel. Approximately 1 km west of Ob Gorm Beag is Balgy Lodge, which accomodates up to 12. Further tourist accommodation is available in Torridon and on the north shore. During the shoreline survey, signs of wild camping were observed on the shore west of the Dubh Aird fishery. The presence of tourist accommodation suggests that the local population may increase significantly during the tourist season, broadly from April to October, although there is likely to be a peak in numbers during July and August.

There are six anchorages on the southern shore of the loch, three of which lie in very close proximity to the mussel farms (Clyde Cruising Club, 2007). Further to the west, facilities for boats including a slipway, pontoon and four moorings, were observed along the southern shore of the loch, 2 km west of the mussel farms. On the northern shore, there is a pier at Inveralligin.

Overall, the impact from human sources to the water quality at the mussel farms is likely to be low due to the low population density of the overall area and largely uninhabited coast south of the fisheries. However, the large number of anchorages off the southern coast, in particular the anchorages located adjacent to the fisheries, and the presence of tourist accommodation in the area suggests a seasonal increase in human population and activity during the spring and summer months, and therefore any potential impact to the fishery would be higher during these times.

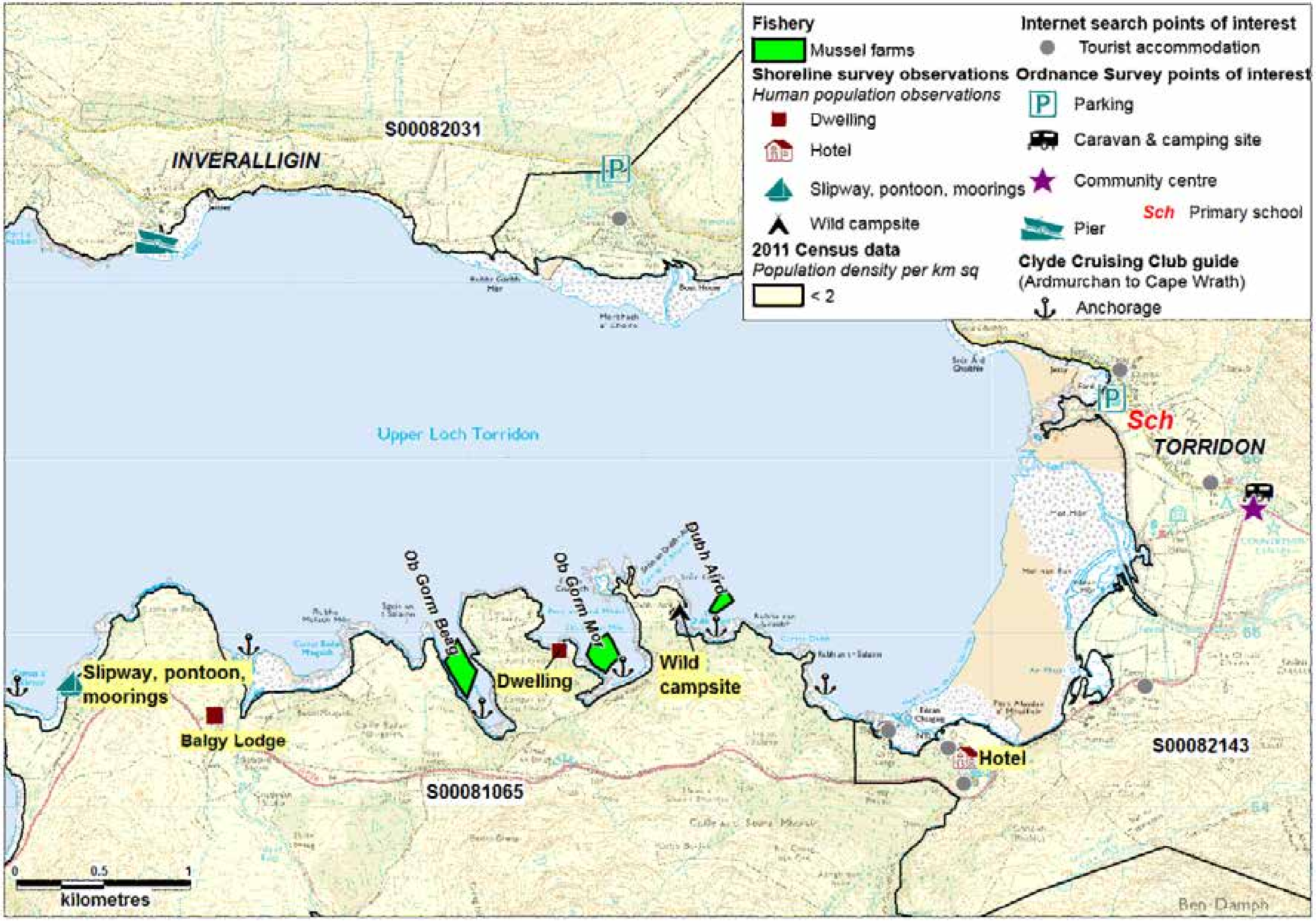

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Figure 3.1 Population map for the area in the vicinity of Inner Loch Torridon

4. Sewage Discharges

Information on sewage discharges within 7.5 km around grid reference NG 855 560 was sought from Scottish Water and the Scottish Environment Protection Agency (SEPA). Data requested included the name, location, type, size (in either flow or population equivalent), level of treatment, sanitary or bacteriological data, spill frequency, discharge destination (to land, watercourse or sea), any available dispersion or dilution modelling studies, and whether improvements were in work or planned.

4.1 Community Discharges

Scottish Water reported two community septic tanks discharging within the area requested, along with six emergency overflows (EO) and five combined sewer overflows (CSO). This is shown in Table 4.1.

Table 4.1 Scottish Water discharges

Licence Number	Site Name	NGR	Discharge Type	Treatment Level	DWF (m^3/d)	PE
CAR/L/1003969	Shieldaig Septic Tank 1995	NG 815 535	FE	Primary	-	-
CAR/L/1002062	Torridon Septic Tank 1960	NG 892 560	FE	Primary	-	-
WPC/N/58385	Shieldaig Hotel WWPS 1995	NG 813 537	EO	N/A	-	-
not in database	Shieldaig Hotel WWPS CSO 1995	NG 813 537	CSO	N/A	-	-
WPC/N/58386	Shieldaig Slipway WWPS 1995	NG 814 540	EO	N/A	-	-
not in database	Shieldaig Slipway WWPS CSO 1995	NG 814 540	CSO	N/A	-	-
WPC/N/58387	Shieldaig Pier WWPS 1995	NG 814 535	EO	N/A	-	-
not in database	Shieldaig Pier WWPS CSO 1995	NG 814 535	CSO	N/A	-	-
WPC/N/58389	Shieldaig Public WWPS 1995	NG 815 542	EO	N/A	-	-
not in database	Shieldaig Public WWPS CSO 1995	NG 815 542	CSO	N/A	-	-
WPC/N/55431	Torridon Youth Hostel WWPS 1981	NG 902 550	EO	N/A	-	-
not in database	Torridon Hostel WWPS CSO 1981	NG 902 550	CSO	N/A	-	-
WPC/N/55432	Torridon Fasaig WWPS 1981	NG 896 565	EO	N/A	-	-

WWPS = Waste Water Pumping Station FE = Final Effluent DWF = Dry Weather Flow, PE = Population Equivalent, N/A = Not Applicable, - = No data provided

The two community septic tanks serve the settlements of Torridon and Shieldaig. Torridon septic tank discharges at the mouth of River Torridon and has two EOs and one CSO associated with it. Shieldaig septic tank discharges to the south of Shieldaig at the head of Loch Shieldaig and has four associated CSOs and EOs.

Neither Scottish Water nor SEPA provided DWF or PE data for either of the septic tanks. However, the 2011 Shellfish Waters Growing Waters report for the area gives a PE of 190 for the Torridon Septic Tank (SEPA, 2011). SEPA provided corroborating information for the EO consents provided by Scottish Water but were unable to provide any information relating to the CSOs (the licences provided related only to the former).

4.2 Consented Private Discharges - SEPA

SEPA provided information regarding consented discharges within the request area identified. Discharges relating to abstraction or engineering works have been excluded from assessment as they do not contribute to any faecal input to the area. The consented discharges assessed in this report are listed in Appendix 6.

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

SEPA provided information on 65 sewage discharge consents around Inner Loch Torridon. SEPA also provided information on two marine cage fish farms (CAR/L/1002917 and CAR/L/1010002) and one freshwater cage fish farm (CAR/L/1003924).

The list of consents did not include those for Torridon Hotel (PE = 170) or the septic tank at the Marine Harvest Shore Base (no PE given): information on these was obtained from the 2011 Shellfish Growing Waters report (SEPA, 2011).

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

The majority of consented private discharges are located on the northern shore of Loch Torridon around the settlements of Inveralligin and Alligin Shauas.

Shoreline Survey Discharge Observations

Five observations of sewage infrastructure were noted during the shoreline survey. These are listed in Table 4.2.

Table 4.2 Discharge-associated observations made during the shoreline survey

No.	Date	NGR	Associated Photograph (Appendix 5)	Description
1	27/08/2013	NG 8636 5514	Fig. 12	Septic tanks cover at lone house on the peninsula. Tank appears to soakaway into marshy ground - no discharge pipe observed.
2	27/08/2013	NG 8881 5433	Fig. 6	Two manholes present in hotel grounds, on path to river
3	27/08/2013	NG 8885 5428	-	Possible location of septic tank - 3x metal manhole covers below hotel in field.

Observation 1 relates to a septic tank associated with a single dwelling observed approximately 400 m to the northwest of the Ob Gorm Mor mussel farm. The tank lies within 50 m of the shoreline, and near marshy ground where the soakaway was presumed to be located. Any overland flow from this soakaway would have the potential to contaminate water nearby and may affect the north end of the Ob Gorm Mor site.

Observations 2 and 3 may relate to septic tank facilities associated with the Loch Torridon hotel. No discharge outlet was seen, however, and therefore it is not clear whether the septic tank discharges to land or to water.

Summary

There are two community septic tanks in the area, one at Shieldaig and one at Torridon. The former is located outside of the present production area and more than 8 km from the nearest mussel farm. The latter is located within 2 km of the mussel farm at Dubh Aird. In addition, the discharges associated with the Torridon Hotel and the other private discharges at Torridon will add to the potential for contamination arising from the head of the loch.

One septic tank, discharging to soakaway, was observed during the shoreline survey at the head of Aird Mhor peninsular adjacent to Ob Gorm Mor: this is less than 400 m from the mussel farm but only serves one dwelling. It is located within the extent of the shellfish farm lease and so the mussel farm could, in principle, expand or move closer to that discharge.

There are also several private discharges along the northern shore of the loch around Inveralligin, however these are located more than 2 km from the north of the mussel farms and are not expected to have a signficant impact there.

List of Acronyms

MDF=	Mean daily flow	DWF=	Dry weather flow
PE=	Population Equivalent	ST=	Septic Tank
WWTW=	Wastewater Treatment Work	CSO=	Combined Sewer Overflow

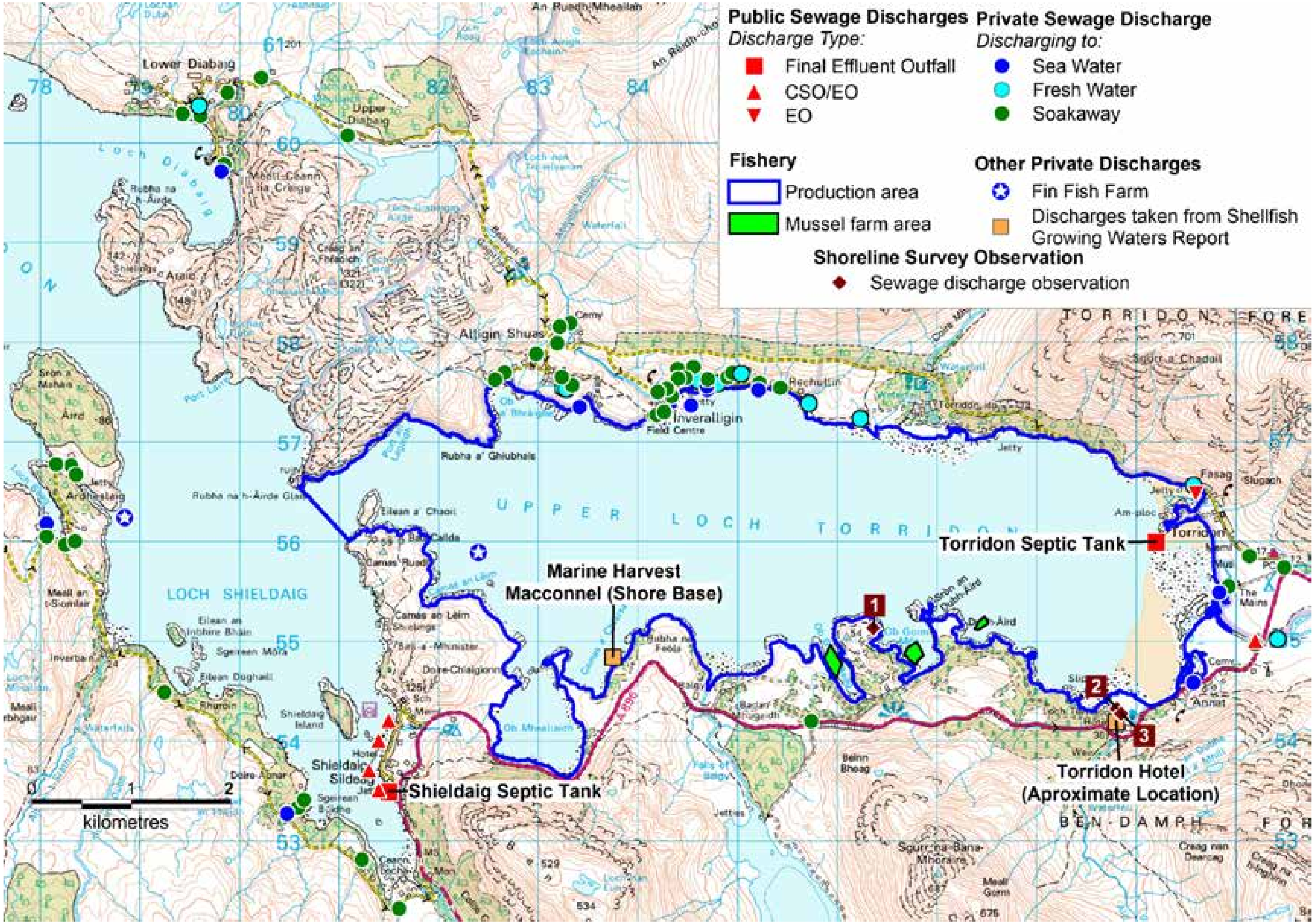

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Figure 4.1 Map of discharges for Inner Loch Torridon

5. Agriculture

Information on the spatial distribution of animals on land adjacent to or near the fishery can provide an indication of the potential amount of organic pollution from livestock entering the shellfish production area. Agricultural census data to parish level was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for the Applecross parish. Reported livestock populations for the parishes in 2012 are listed in Table 5.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reporting would have made it possible to discern individual farm data. Any entries which relate to less than five holdings, or where two or fewer holdings account for 85% or more of the information, are replaced with an asterisk.

Table 5.1 Livestock numbers in the Applecross agricultural parish 2012

	Applecross	
	450 km^2	
	Holdings	Numbers
Pigs	7	134
Poultry	16	402
Cattle	10	192
Sheep	33	6085
Other horses and ponies	*	*

The livestock census numbers for Applecross relate to very a large parish area: therefore it is not possible to determine the spatial distribution of the livestock on the south side of the loch in relation to the area adjacent to the fisheries, or identify how many animals are likely to impact the catchment around the mussel farms. However, the figures do give an idea of the total numbers of livestock over the broader area. Sheep were present in moderate numbers with pigs, poultry and cattle present in small numbers. There were less than five holdings of other horses and ponies. Considering the size of area, there is relatively very little livestock production in the area compared with other Scottish parishes.

No livestock, farms or agricultural buildings were observed along the survey route during the site visit undertaken on the 26th – 27th August 2013.

However, a Highland Council planning application report refers to “...an area of open croft land on the western (seaward) side of the public road which runs through Torridon Village...” and “The site forms part of an expansive strip of agricultural land between the public road and the shore of Loch Torridon...” (The Highland Council, 2013). Inspection of aerial imagery showed the presence of significant numbers of sheep on grassland at the head of the loch (Bing Maps, accessed 17/03/14).

Faecal contamination from agricultural sources is likely to be primarily associated with the area at the head of the loch.

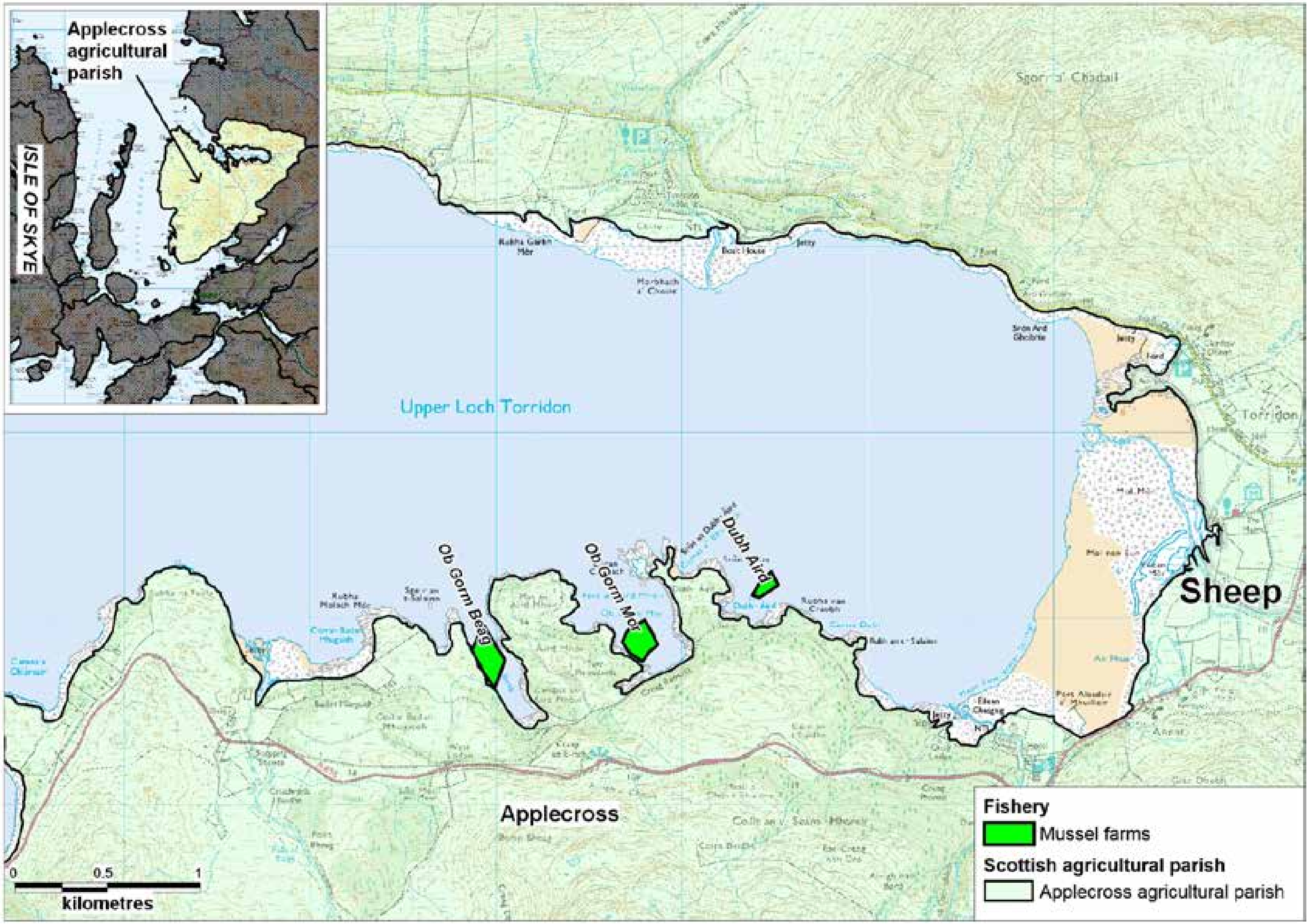

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Figure 5.1 Extent of the agricultural parish in the vicinity of Inner Loch Torridon

6. Wildlife

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

The species most likely to contribute to faecal indicator levels at the Inner Loch Torridon common mussel fisheries are considered below.

Pinnipeds

In a report by the Special Committee on Seals (2012) on the West coast of Scotland between Cape Wrath and Ardnamurchan Point, 4696 harbour seals were observed in 2007 and 2008. There are anecdotal accounts of there being a seal colony within Upper Loch Torridon (Torridon Sea Tours, 2014), thought this cannot be verified. During the shoreline survey no seals were observed.

Cetaceans

There are reports of common dolphins in Upper Loch Torridon (Seawatch Foundation, 2014). There are also anecdotal accounts of harbour porpoise (Ben Damph Estate, 2014). During the shoreline survey no cetaceans were observed.

Birds

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

Table 6.1 Seabird counts within 5 km of Inner Loch Torridon

Common name	Species	Count	Method
Black guillemot	*Cepphus grylle*	11	Individuals on land

Data in Table 6.1 suggests there is little contamination impact from birds in the area around Inner Loch Torridon. However, large numbers of birds at occupied sites and nesting sites for European shags, great cormorant, great black-backed gulls and European herring gulls were situated >6 km west of Inner Loch Torridon. Birds from these colonies may at times use the surrounding Loch Torridon area.

No birds were observed during the shoreline survey.

Deer

Two species of deer are likely to be found on land surrounding Inner Loch Torridon: red deer and roe deer (Ben Damph Estate, 2014). Red deer are likely to come down from the hills during winter months and inhabit land at sea level. Roe deer are most likely to be found in woodland, and use open grassland in which to graze. There are also accounts of both sika and fallow deer in the area (The Torridon, 2014). During the shoreline survey no deer were observed.

Otters

The Eurasian otter (*Lutra lutra*) is common around the lochs along the west coast of Scotland (The Torridon, 2014). Although there are no official reports of otters within Loch Torridon, there are anecdotal reports indicating that otters can be observed around the outskirts of Torridon village (Walkhighlands, 2013). During the shoreline survey, no otters were observed.

Overall

Species potentially impacting on Inner Loch Torridon include seals, cetaceans, birds, deer and otters. No significant populations were noted within 5 km of any of the Inner Loch Torridon fisheries. While it is certain that wild animals will contribute to background levels of faecal contamination around the loch, little is known about the spatial distribution of wild animals and their impacts. For the purposes of this report, even distribution and impact across the fishery will be assumed in the absence of more specific information.

7. Land Cover

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

Coniferous woodland, broad leaf woodland, rough grassland and dwarf shrub heath are the predominant land cover types on the coast adjacent to Inner Loch Torridon mussel farms. There are also scattered small areas of improved grassland, bog, acid grassland and montane habitats. A small built up area is represented southeast of the fishery, where houses and a hotel were observed during the shoreline survey.

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

The risk of faecal contamination based on landcover type is therefore considered to be low but would increase to some extent after rainfall (no improved grassland was identified adjacent to the fisheries).

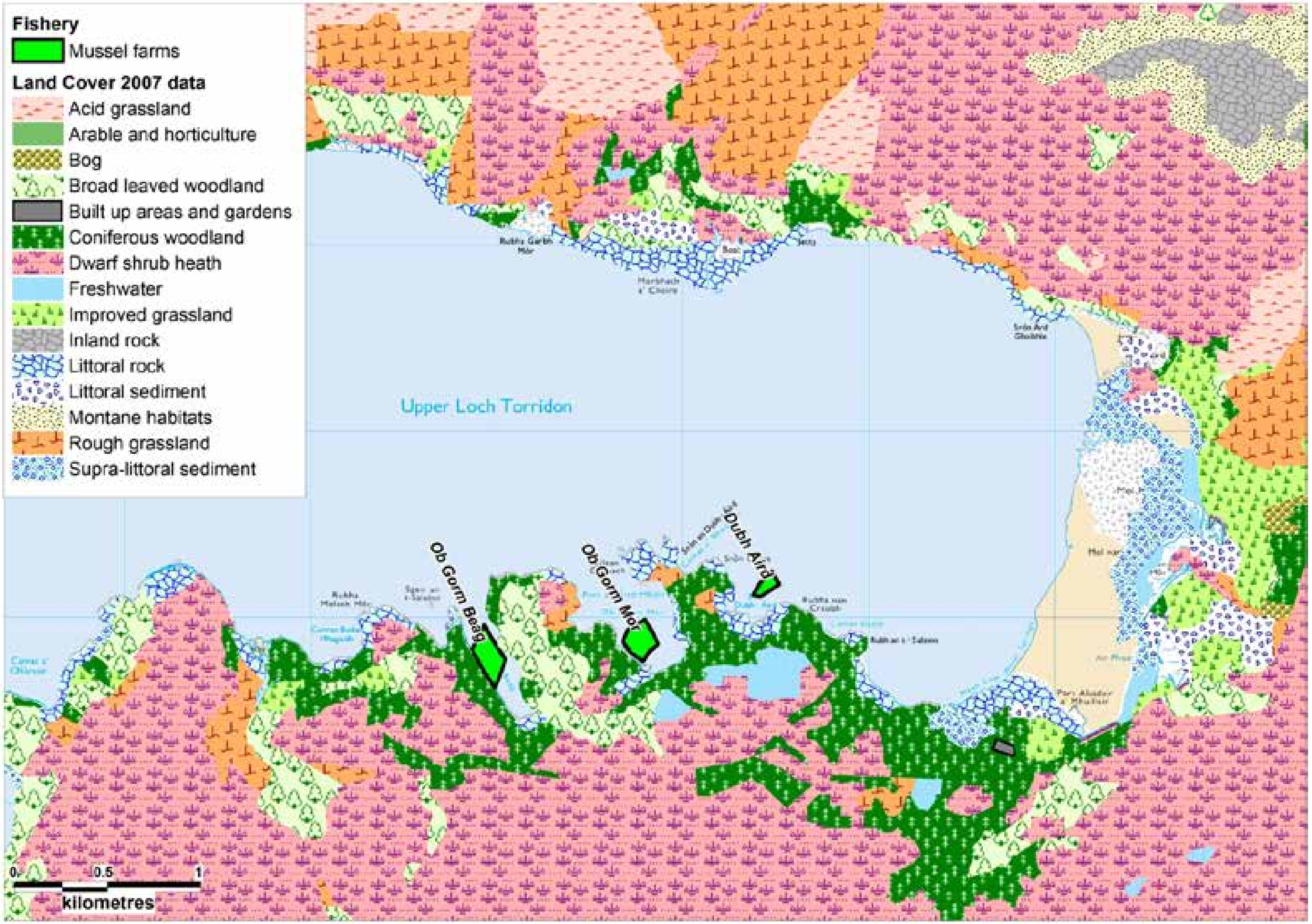

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Figure 7.1 LCM2007 land cover data for the area around Inner Loch Torridon

8. Watercourses

There are no gauging stations on watercourses entering Inner Loch Torridon.

Spot measurements of flow and microbial content were obtained during the shoreline survey conducted on the 26th and 27th August 2013. No precipitation was recorded in the 48 hrs prior to the survey. The watercourses listed in Table 8.1 are those recorded during the shoreline survey.

No areas of land drainage were observed. The depths of watercourses No. 5 and 6 were not recorded therefore it is not possible to estimate loadings.

Table 8.1 Watercourses entering Inner Loch Torridon

No.	NGR	Description	Width (m)	Depth (m)	Flow (m^3/d)	*E. coli* cfu/100 ml	Loading (*E. coli* per day)
1	NG 84227 57360	Abhainn Alligin	5.20	0.29*	26058*	10	2.6×10^9
2	NG 87071 57166	Abhainn Coire Mhic Nobuil	5.10	0.375**	54199**	<10	$<5.4 \times 10^9$
3	NG 90258 55017	River Torridon and the Abhainn Thrail	4.70	0.485**	79272**	<10	$<7.9 \times 10^9$
4	NG 88808 54330	Allt Coire Roill	4	0.21**	20249**	<10	$<2.0 \times 10^9$
5	NG 86646 54537	Unnamed burn	0.30	NA	NA	NA	Not determined
6	NG 86195 54341	Unnamed burn	0.50	NA	NA	NA	Not determined
7	NG 85872 54661	Unnamed burn	0.45	0.06	236	10	2.4×10^7
8	NG 84695 54290	River Balgy	11	0.285***	165498***	<10	$<1.7 \times 10^{10}$
9	NG 84695 54290	River Balgy	5.50	0.17**	31546**	<10	$<3.2 \times 10^9$

* Average taken from three measurements ** Average taken from two measurements
*** Average taken from four measurements

E. coli concentrations in the watercourses sampled during the shoreline survey were very low, all giving results of <10 or 10 *E. coli* cfu/100 ml. Loadings could only be estimated for two of the watercourses and these were low to moderate. The low extent of contamination at the time of the shoreline survey may have been related to the fact that it was undertaken after a period of dry weather. In wet weather, both flow and contamination levels may be higher.

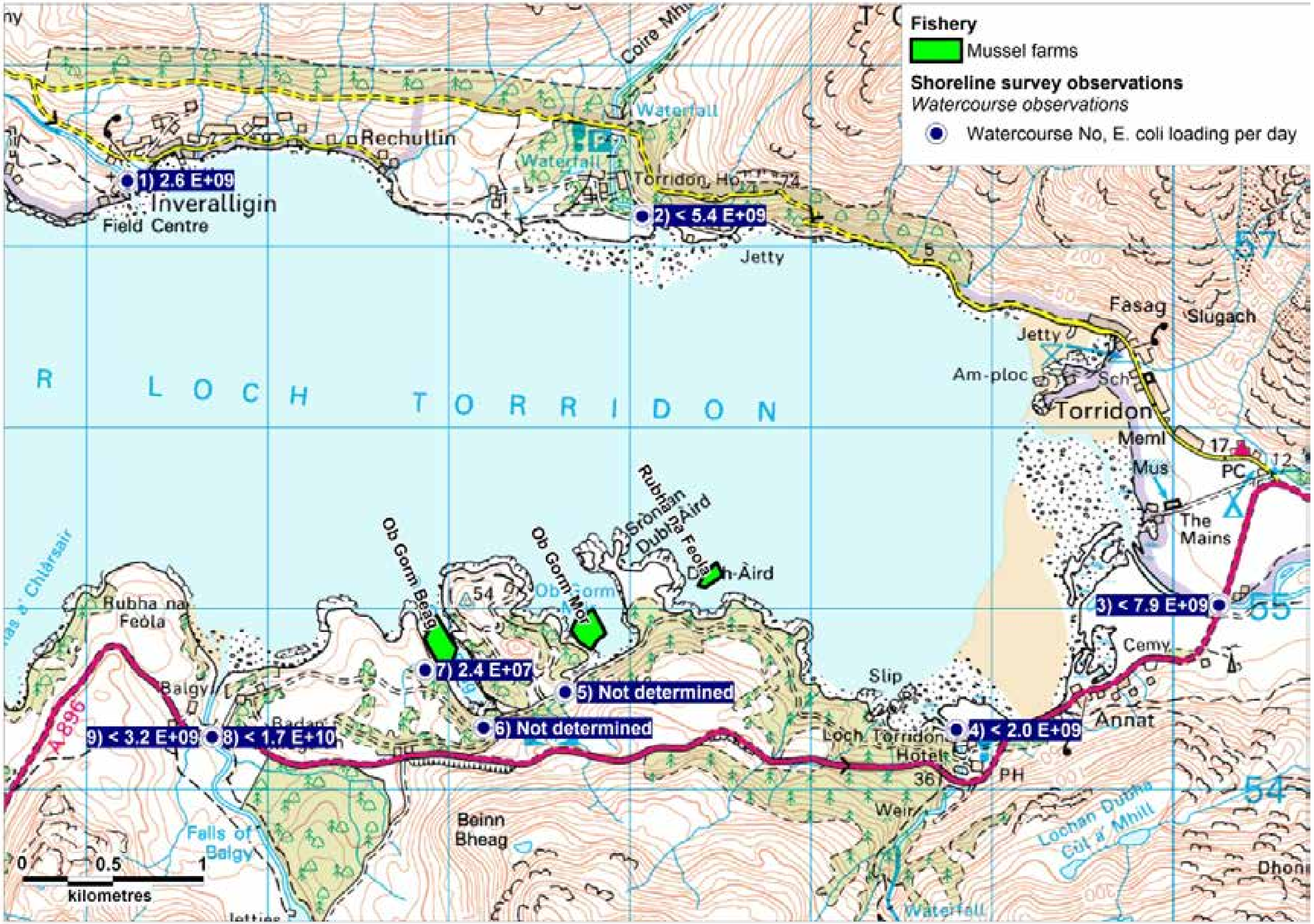

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Figure 8.1 Map of watercourse loadings at Inner Loch Torridon

9. Meteorological Data

The nearest weather station is located at Torridon, on the eastern coast of the loch. However, the 2011 dataset for this station consisted mostly of estimates and accumulated totals rather than measurements. In addition, two months data was missing from the 2010 dataset. Therefore, data from this stantion has not been used. The nearest weather station with the most complete rainfall data history is located at Skye; Lusa, situated approximately 33 km south west of the fishery. Rainfall data was available for January 2007 – August 2012 at the time of writing this report. The nearest wind station is situated at Stornoway Airport, approximately 85 km north west of the fishery. 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 the purchased 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 Inner Loch Torridon.

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 *.

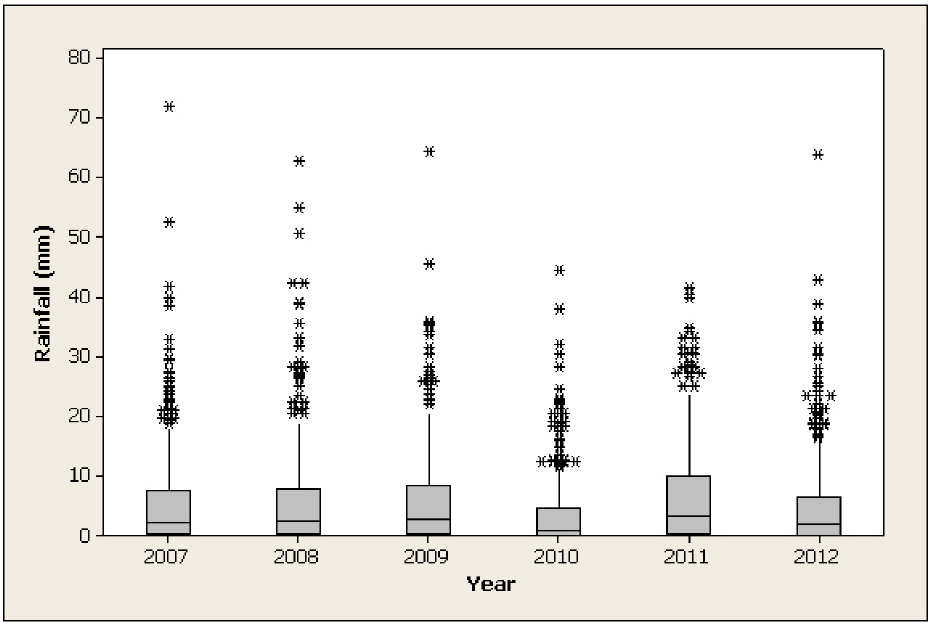

Figure 9.1 Box plot of daily rainfall values by year at Skye; Lusa (2007 – 2012)

Total rainfall values varied from year to year, with 2010 being the driest year (a total of 1341 mm). The wettest year was 2011 (a total of 2515 mm). High daily rainfall values of more than 30 mm/d occurred in all years and extreme rainfall events of more than 60 mm/d were seen in all but the wettest and driest years.

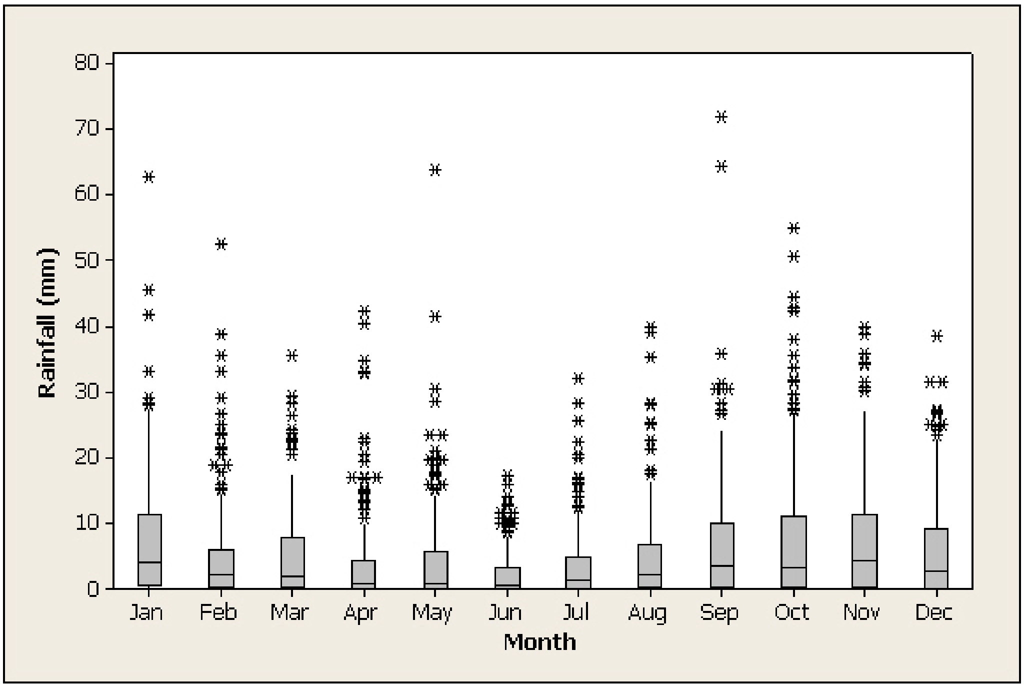

Figure 9.2 Box plot of daily rainfall values by month at Skye; Lusa (2007 – 2012)

Rainfall was lowest between April and July and highest between September and January. Rainfall values exceeding 30 mm/d were seen in all months except June.

For the period considered here (2007 – 2012) 40% of days received daily rainfall of less than 1 mm and 19% of days received rainfall of greater than 10 mm.

It is therefore expected that rainfall associated run-off will be higher during the autumn and winter months. However, extreme rainfall events leading to episodes of high runoff has occurred in most months.

9.2 Wind

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

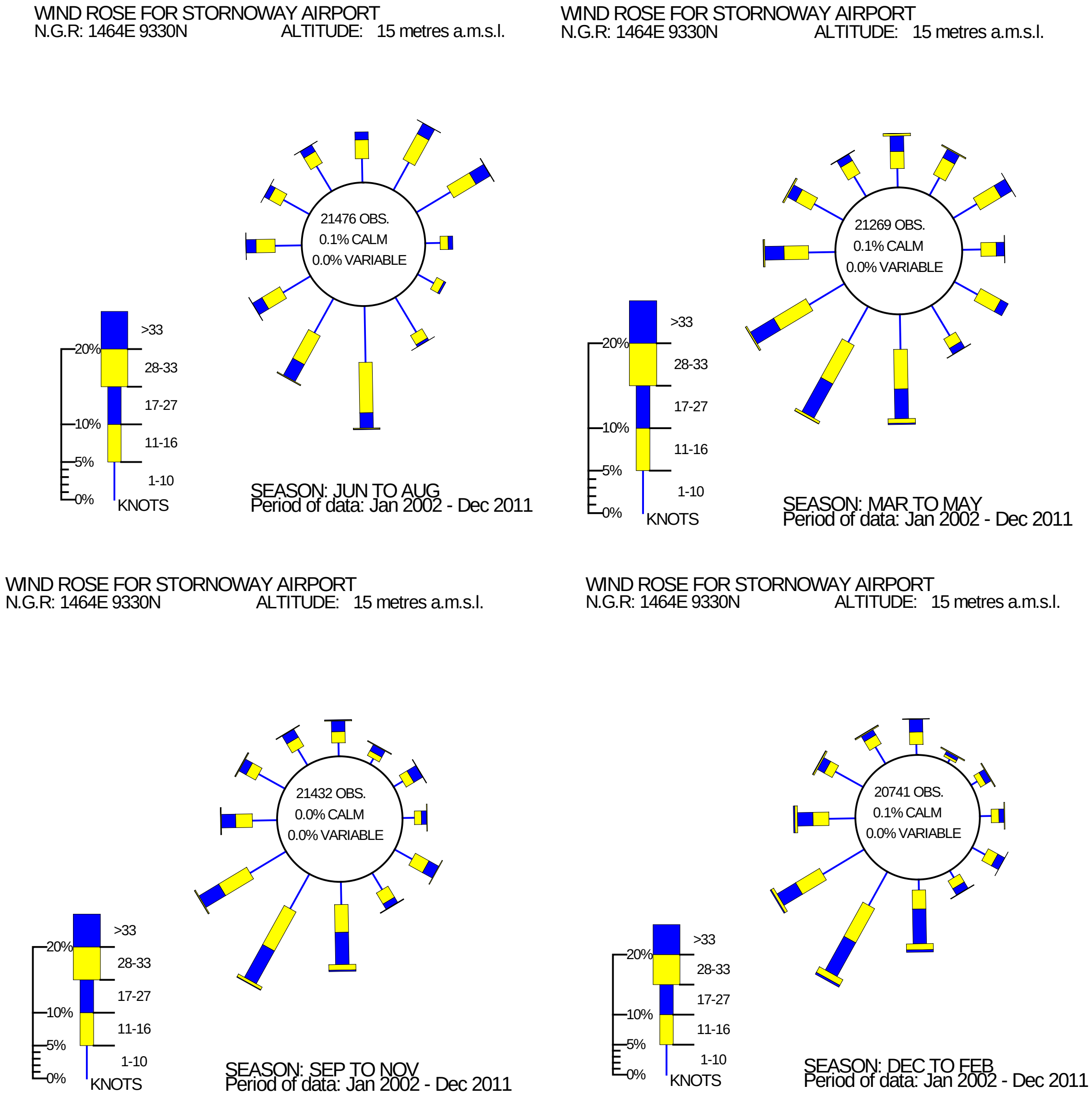

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Figure 9.3 Seasonal wind roses for Stornoway Airport

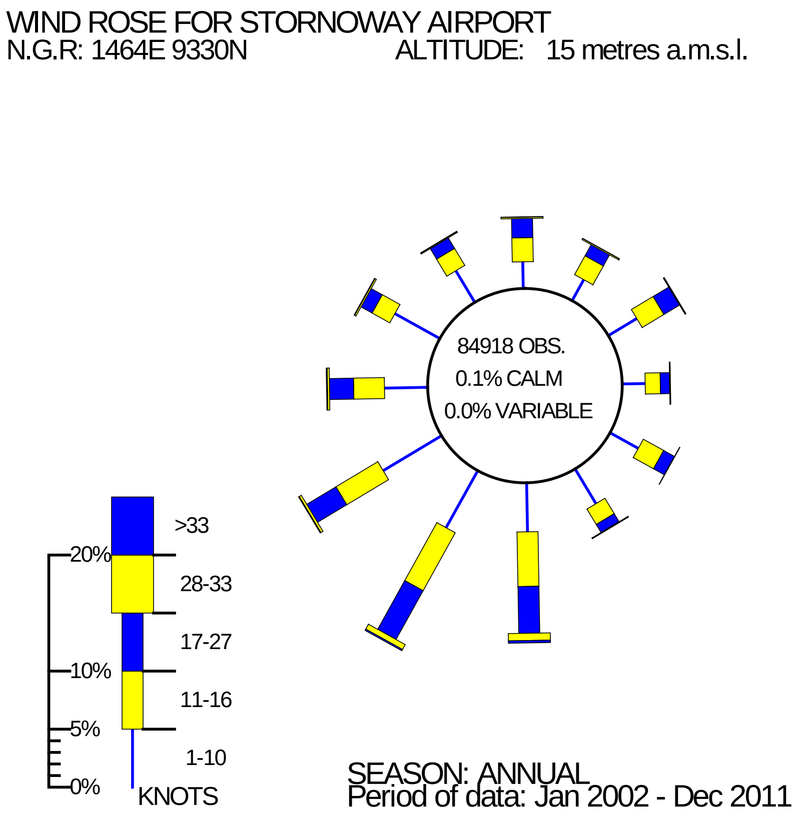

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Figure 9.4 Annual wind rose for Stornoway Airport

Overall, winds were predominantly from the southwest. However, during summer, southerly winds predominated and there were also relatively strong winds from the north-west. Wind is an important factor in the spread of contamination as it has the ability to drive surface water at about (3%) of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s. Therefore strong winds can significantly alter the pattern of surface currents. Strong winds also have the potential to affect tide height depending on wind direction and local hydrodynamics of the site. A strong wind combined with a spring tide may result in higher than usual tides, which will carry any accumulated faecal matter at and above the normal high water mark into the fishery area.

10. Classification Information

Inner Loch Torridon is classified for production of common mussels (*Mytilus edulis*) and has been classified for production since 2001. The classification history since 2006 is listed in Table 10.1

Table 10.1 Inner Loch Torridon 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	B	B	B	A	A	A
2010	A	A	A	A	B	B	B	B	B	B	B	A
2011	A	A	A	A	A	B	B	B	B	B	B	A
2012	A	A	A	A	B	B	B	B	A	A	A	A
2013	A	A	A	A	A	A	A	A	A	A	A	A
2014	A	A	A									

11. Historical *E. coli* Data

11.1 Validation of historical data

Results for all samples assigned against Inner Loch Torridon for the period 01/01/2008 to 10/10/2013 were extracted from the FSAS database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. The data was extracted from the database on 10/10/2013. All *E. coli* results were reported as most probable number (MPN) per 100 g of shellfish flesh and intravalvular fluid.

All sample results reported as <20 were reassigned a value of 10 *E. coli* MPN/100 g and results >18000 were reassigned values of 36000 *E. coli* MPN/100 g for the purposes of statistical evaluation and graphical representation.

Two samples did not have results recorded and were omitted from further analysis in this report. The remaining 69 results were reported as valid, were received at the laboratory within 48 hours of collection and had reported grid references that plotted within 100 m of the production area boundary.

11.2 Summary of microbiological results

Table 11.1 Summary of historical sampling and results

Sampling Summary	
Production area	Inner Loch Torridon
Site	Ob Gorm Mor
Species	Common mussels
SIN	RC-090-245-08
Location	Various
Total no of samples	69
No. 2008	12
No. 2009	10
No. 2010	11
No. 2011	11
No. 2012	12
No. 2013	12
No. 2014	1
Results Summary	
Minimum	<20
Maximum	>18000
Median	20
Geometric mean	49
90 percentile	790
95 percentile	2050
No. exceeding 230/100g	14 (20%)
No. exceeding 1000/100g	5 (7%)
No. exceeding 4600/100g	2 (3%)
No. exceeding 18000/100g	1 (1%)

The majority of results have been low, though the highest sample result was >18000 *E. coli* MPN/100 g.

11.3 Overall geographical pattern of results

The geographical locations of all 69 sample results assigned to Inner Loch Torridon are mapped thematically in Figure 11.1. The majority of samples are reported to have been taken within Ob Gorm Mor on the southern shore, except for one sample (<20 *E. coli* MPN/100 g) that was taken approximately 1.7 km north of the RMP at NG 8696 5672.

Twenty-five samples from 2011-2014 have been taken within 20 m of the current RMP at NG 8697 5502, with the remaining samples from 2008-2011 taken <500 m south and southwest. Only one sample was taken within the current mussel farm boundaries, with the other samples taken within the intertidal area along the surrounding shoreline.

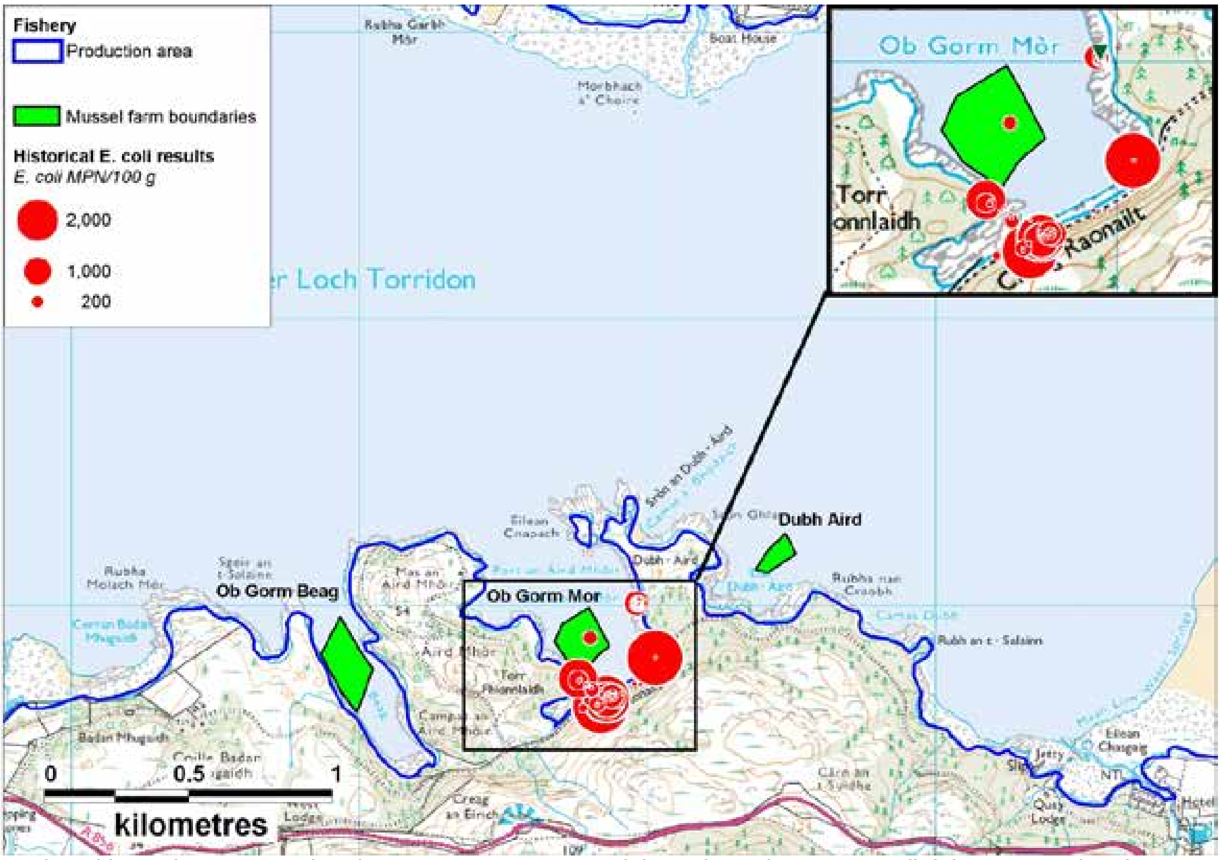

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Figure 11.1 Map of reported sampling locations at Inner Loch Torridon

A one-way ANOVA was used to test for significant differences in sampling results between two different sampling localities: around the RMP and south/southwest of the RMP. No statistically significant difference was found (one-way ANOVA, $p = 0.137$) (Appendix 4). However, the highest results were reported against locations to the south/southwest of the RMP.

11.4 Overall temporal pattern of results

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

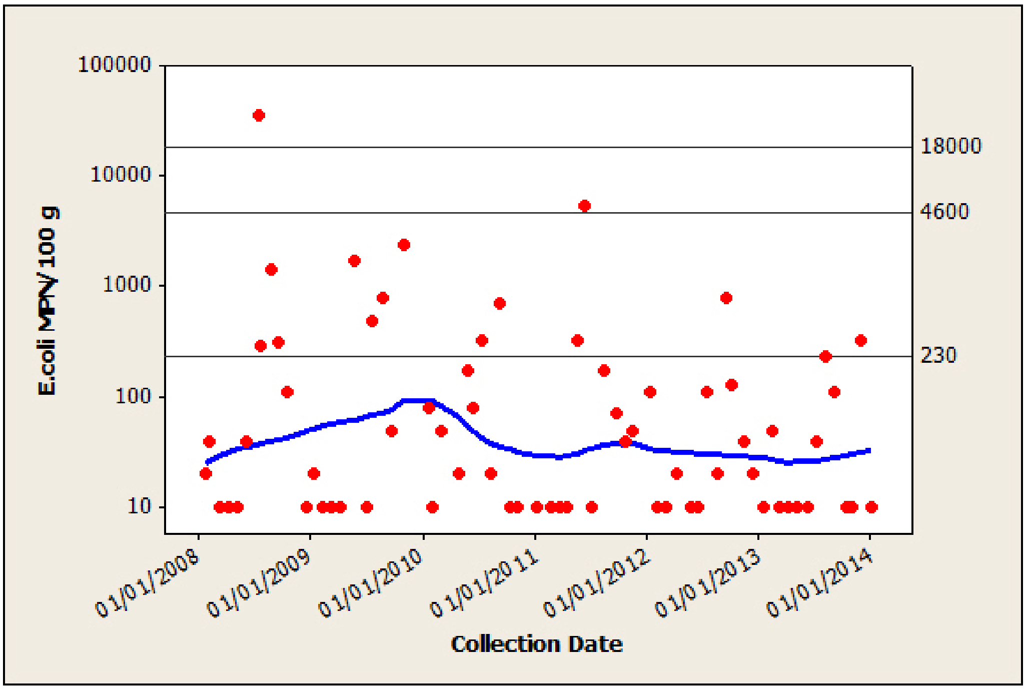

Figure 11.2 Scatterplot of *E. coli* results by collection date at Inner Loch Torridon, fitted with a lowess line

Contamination levels have been generally stable although there was a small peak in the trend line around the end of 2009 and beginning of 2010. This was largely due to the absence of very low 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. Scatterplots of *E. coli* results by month, overlaid by a lowess line to highlight trends for Inner Loch Torridon are displayed in Figure 11.3. Jittering was applied at 0.02 (x-axis) and 0.001 (y-axis) respectively.

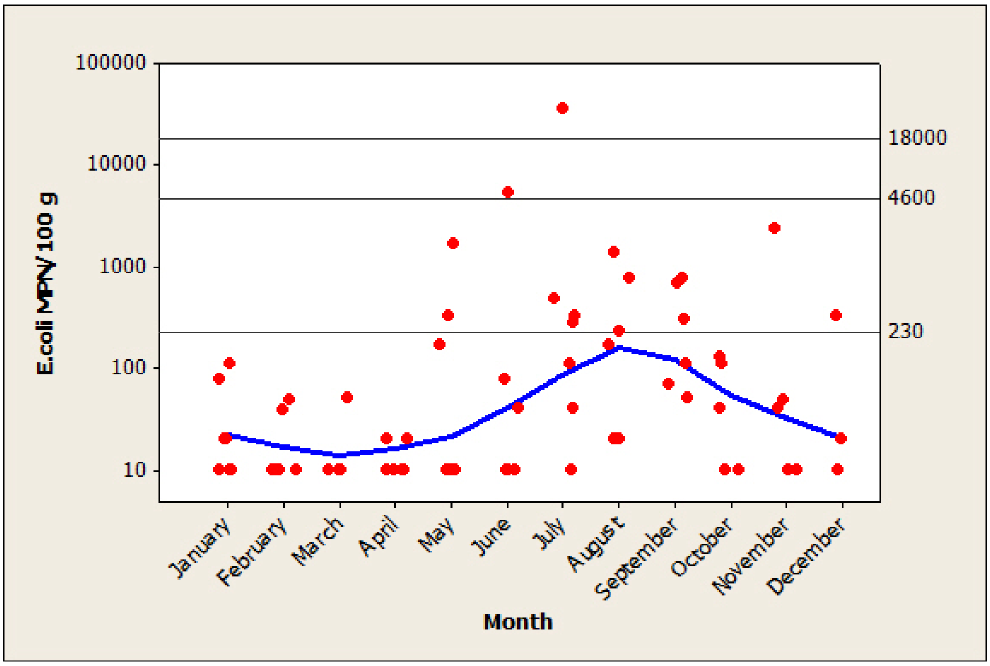

Figure 11.3 Scatterplot of *E. coli* results by month at Inner Loch Torridon, fitted with a lowess line

Results appeared to be lowest from February to April and results exceeding 230 *E. coli* MPN/100 g occurred from late April onward. The highest results (>4600 *E. coli* MPN/100 g) occurred in June and July.

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 Inner Loch is presented in Figure 11.4.

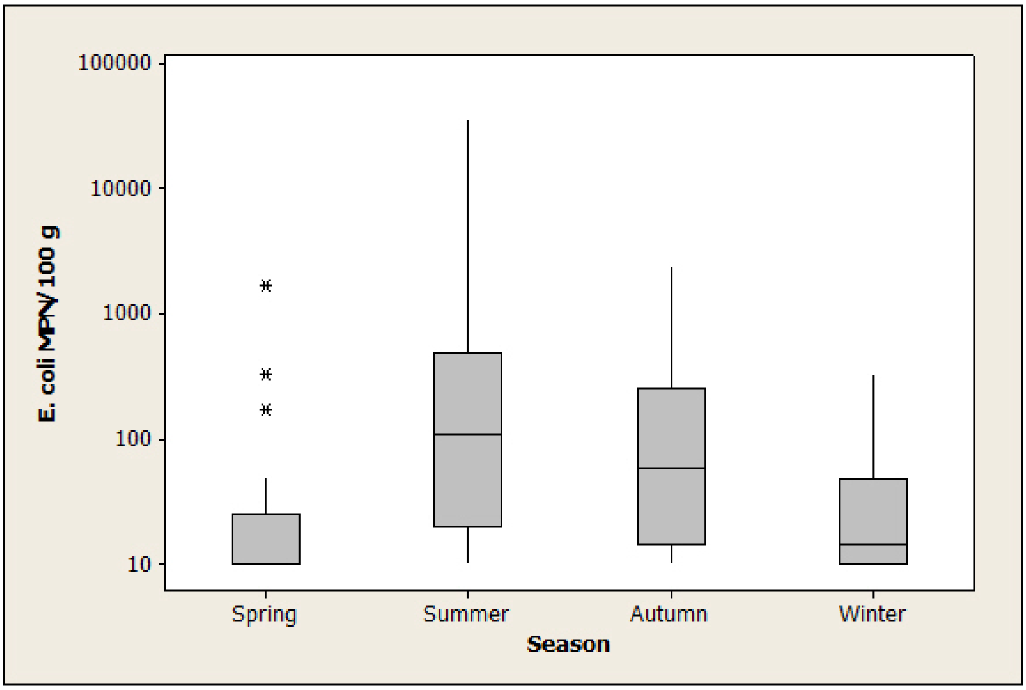

Figure 11.4 Boxplot of *E. coli* results by season at Inner Loch Torridon

A statistically significant difference was found between *E. coli* results by season (one-way ANOVA, p = 0.004) (Appendix 4). Results in summer were significantly higher than in spring 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 Skye: Lusa approximately 33 km southwest of Inner Loch Torridon. Rainfall data was purchased from the Meteorological Office for the period of 01/01/08 - 31/12/2012 (total daily rainfall in mm). Data was extracted from this for all sample results between 01/01/2008 – 31/12/2012.

Two-day rainfall

A scatterplot of *E. coli* results against total rainfall recorded on the two days prior to sampling for Inner Loch Torridon are displayed in Figure 11.5. Jittering was applied to results at 0.02 (x-axis) and 0.001 (y-axis) respectively.

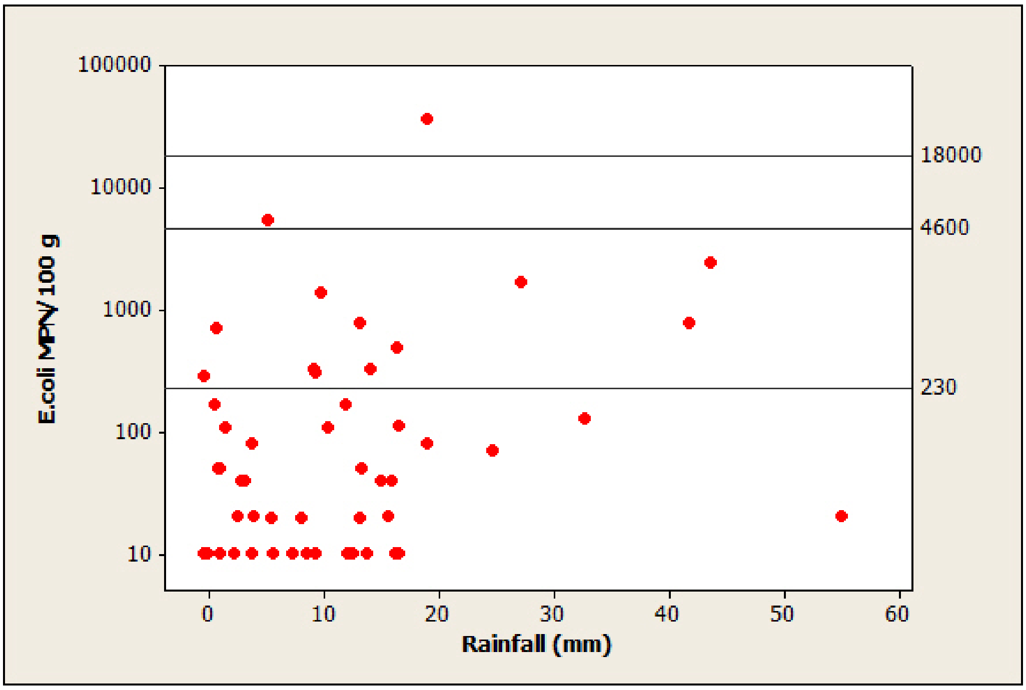

Figure 11.5 Scatterplot of *E. coli* results against rainfall in the previous two days at Inner Loch Torridon

A significant correlation was found between *E. coli* results and the previous two day rainfall (Spearman's rank correlation r = 0.382, p = 0.004), with lower results largely absent at rainfall levels greater than 18 mm. However, it is important to note that one result exceeding 4600 *E. coli* MPN/100 g occurred after two day rainfall of less than 10 mm, which suggests that not all contamination affecting the fishery is rainfall dependent.

Seven-day rainfall

As the effects of heavy rainfall may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationship between rainfall in the previous seven days and sample results was investigated in an identical manner to the above. Scatterplots of *E. coli* results against total rainfall recorded for the seven days prior to sampling at Inner Loch Torridon are shown in Figure 11. Jittering was applied to results at 0.02 (x-axis) and 0.001 (y-axis) respectively.

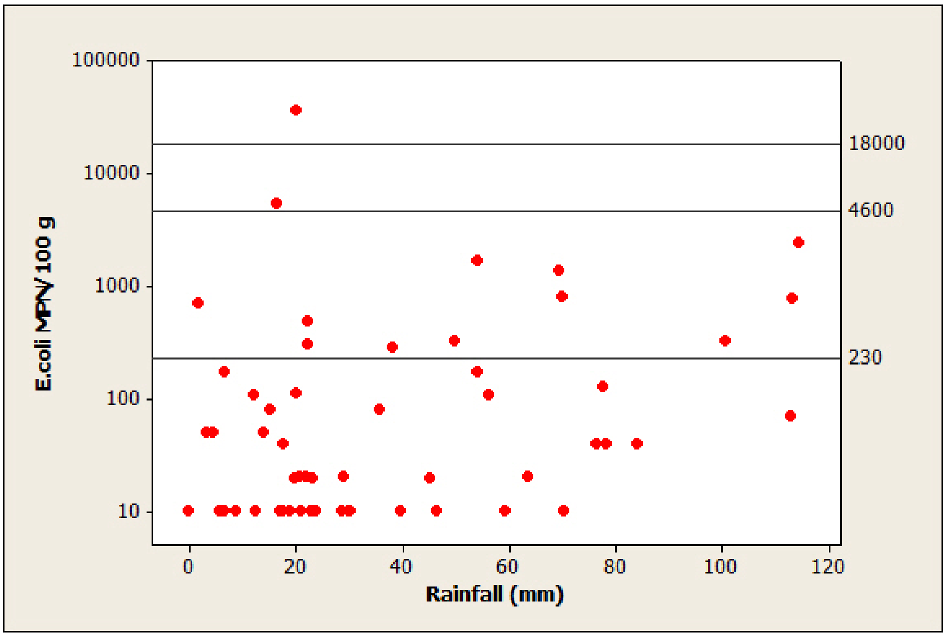

Figure 11.6 Scatterplot of *E. coli* results against rainfall in the previous seven days at Inner Loch Torridon

No significant correlation was found between *E. coli* results and the previous seven day rainfall (Spearman's rank correlation r = 0.240, p = 0.075). Both very high results occurred after relatively very low seven day rainfall totals.

11.6.2 Analysis of results by tidal cycles

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 moon (at about 45^{o} on the polar plot below). The tide then decreases to the smallest neap tides, at about 225^{o}, before increasing back to spring tides. A polar plot of *E. coli* results against the lunar cycle is shown for Inner Loch Torridon in Figure 11.7**.** It should be noted local meteorological conditions (e.g. wind strength and direction) can also influence tide height, but is not taken into account in this section.

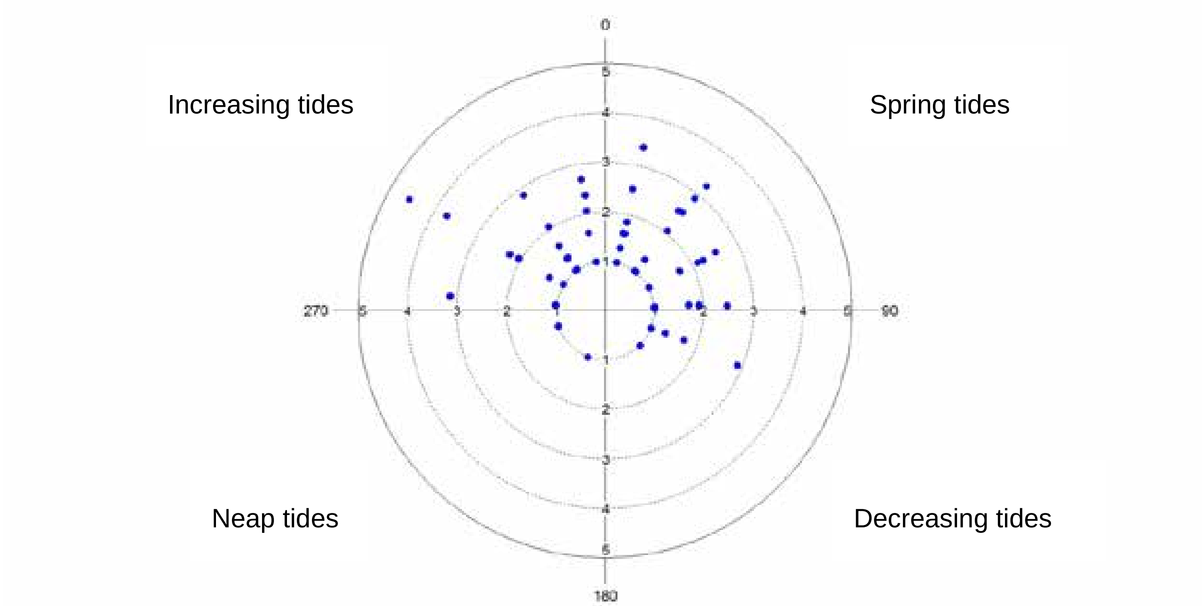

Figure 11.7 Polar plots of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle at Inner Loch Torridon

No significant correlation was found between $\log_{10}$ *E. coli* results and the spring/neap tidal cycle (circular-linear correlation r = 0.208, p = 0.058), with the majority of results taken on increasing and spring tidal states.

High/Low Tidal Cycle

The change of tide from high to low and back 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 Inner Loch Torridon is shown in Figure 11.8. On the polar plot, high water is located at 0^{o} and low water at 180^{o}.

High and low water data from Sheildag was extracted from POLTIPS-3 in February 2014. This site was the closest to the production area and it is assumed that tidal state will be similar between the two locations.

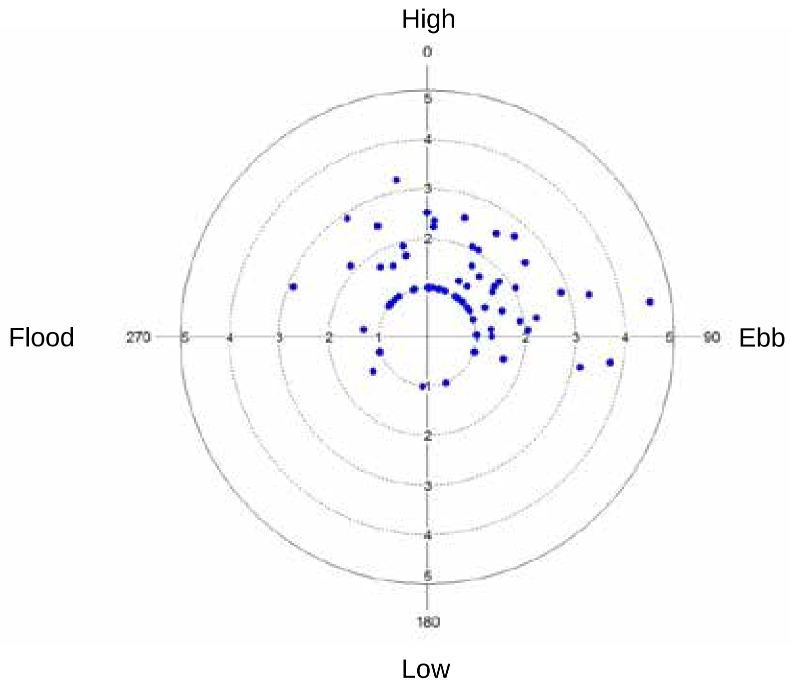

Figure 11.8 Polar plots of $\log_{10}$ *E. coli* results on the high/low tidal cycle at Inner Loch Torridon

No significant correlation was found between $\log_{10}$ *E. coli* results and the high/low tidal cycle (circular-linear correlation r = 0.189, p = 0.095). Most samples were taken around high tide, and very few samples were taken at low tide.

11.6.3 Analysis of results by water temperature

Water temperature can affect survival time of bacteria in seawater (Burkhardt, *et al*., 2000). It can also affect the feeding and elimination rates in shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. Water temperature is obviously closely related to season. Any correlation between temperatures and *E. coli* levels in shellfish flesh may therefore not be directly attributable to temperature, but to the other factors e.g. seasonal differences in livestock grazing patterns. A scatterplot of *E. coli* results against water temperature for Inner Loch Torridon is shown in Figure 11.9. Water temperature was recorded for 65/69 Inner Loch Torridon samples. Jittering of results was applied at 0.02 (x-axis) and 0.001 (y-axis) respectively.

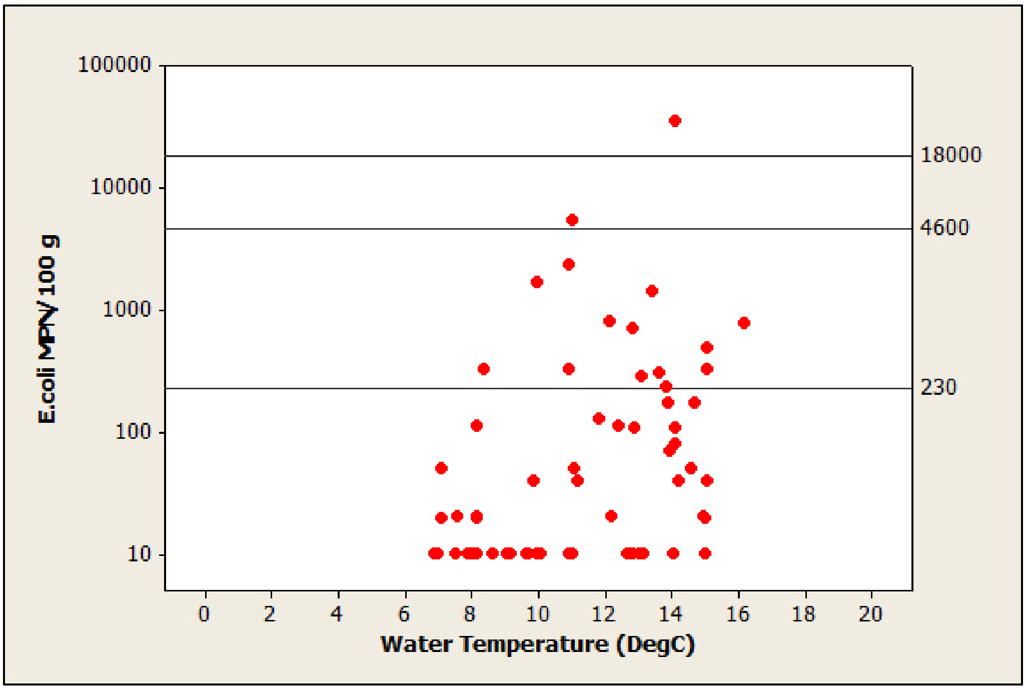

Figure 11.9 Scatterplot of *E. coli* results against water temperature at Inner Loch Torridon

A significant correlation was found between *E. coli* results and water temperature (Spearman's rank correlation r = 0.434, p = 0.000). The highest results occurred at temperatures greater than 10°C, however low results occurred across all recorded water temperatures.

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 Inner Loch Torridon is shown in Figure 11.10. Salinity was recorded for 47/69 of the Inner Loch Torridon samples. Jittering of results was applied at 0.02 and 0.001 on the X and Y axis respectively

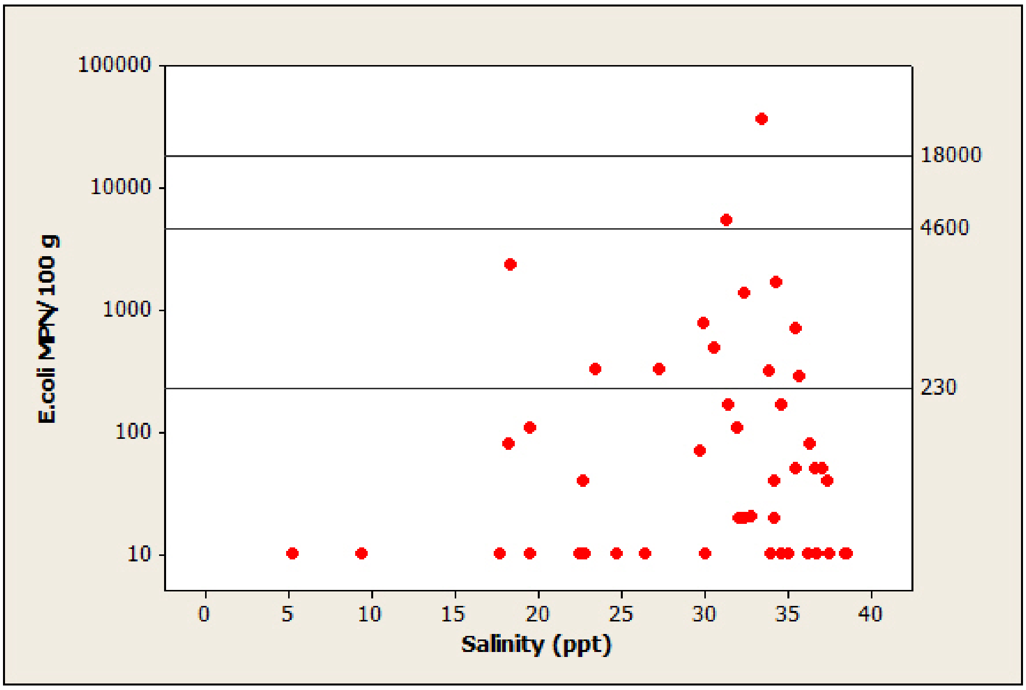

Figure 11.10 Scatterplot of *E. coli* results against salinity at Inner Loch Torridon

No significant correlation was found between common mussel *E. coli* results and salinity (Spearman's rank correlation r = -0.043, p = 0.772).

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

Five common mussel samples from Inner Loch Torridon gave results >1000 *E. coli* MPN / 100 g and are listed below in Table 12.2.

Table 11.2 Inner Loch Torridon historic *E. coli* sampling results over 1000 *E. coli* MPN / 100 g

Collection Date	*E. coli* (MPN/ 100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (^oC)	Salinity (ppt)	Tidal state (spring/neap)	Tidal State (high/low)
15/07/2008	>18000	NG 8684 5465	18.2	20.8	14	34	Increasing	High
27/08/2008	1400	NG 8686 5467	10.4	69.8	13.5	32	Increasing	Ebb
25/05/2009	1700	NG 8676 5475	27.4	53.3	10	34	Spring	Flood
02/11/2009	2400	NG 8686 5468	43.2	113.4	11	18	Spring	High
13/06/2011	5400	NG 8703 5482	5.6	16.8	11	31	Increasing	Ebb

-No data available

Samples were taken in 2008, 2009 and one in 2011. Most of the samples were taken in late spring or summer, with the exception of one sample in November. Location also varied, though the majority plotted southwest of the current RMP. Rainfall over the previous two days and seven days varied. Temperature and salinity also varied. All samples were taken on either an increasing or spring tide, mostly on high/ebb tides, except for the lowest sample result which was recorded on a flood tide.

11.8 Summary and conclusions

Historical results between 2008 and 2011 have shown to have been mostly taken along the intertidal area of the south and southwest shoreline, >100 m from the current RMP. Sampling results taken since the end of 2011 have been taken within <20 m of the RMP, which lies 250 m east of the current mussel farm boundaries. No statistically significant difference was found between results and sampling location, though the highest samples were taken to the south/southwest of the RMP.

Contamination levels are shown to have generally decreased over the sampling period, with fewer results >230 *E. coli* MPN/100 g since 2011, when the sampling location moved. A strong increase in results is shown across months, with the majority of results in August >230 *E. coli* MPN/100 g. However, the two results >4600 *E. coli* MPN/100 g were recorded in June and July. This created the strong statistically significant difference in results between seasons, with highest results in summer.

Statistically significant correlations were found in previous two day rainfall, where the majority of high results were taken when rainfall levels were >10 mm, though no correlation was found between results and seven day rainfall. A statistically significant correlation was also found between results and water temperature, where the majority of results >230 *E. coli* MPN/100 g were taken at >10^{o}C, though no correlation was found between results and water salinity.

No statistically significant correlation was found between *E. coli* results and spring/neap or high/low tidal states.

12. Designated Waters Data

Shellfish Water Protected Areas

The Shellfish Waters Directive (2006/113/EC) has been repealed (as at 31st 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 Upper Loch Torridon Shellfish Water Protected Area (SWPA) has identical boundaries to the previous Upper Loch Torridon Shellfish Growing Water (SGW). The SWPA designation covers the entire upper loch and includes the Inner Loch Torridon mussel farms. There is an historic SGW monitoring point located at NG 833 537. Since 2007, SEPA has used the FSAS *E. coli* data for assessing microbiological quality. The designated SWPA for Upper Loch Torridon is shown in Figure 12.1.

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Figure 12.1 Designated shellfish water protected area – Upper Loch Torridon

Bathing Waters

There are no designated bathing waters within Loch Torridon.

13. Bathymetry and Hydrodynamics

13.1 Introduction

13.1.1 The Study Area

Loch Torridon is situated in the northwest Highlands of Scotland, to the east of the Isle of Skye. The loch has three sections, Outer Loch Torridon, Loch Shieldaig, and Inner Loch Torridon. It is the Inner section of loch Torridon (often referred to as ‘Upper’ on charts and other publications) which is the area of interest in this study. The boundary between Loch Shieldaig and Inner Loch Torridon to the east is the headland of Rubha na h-Airde Ghlaise. Inner Loch Torridon contains two islands which form at low water; Eilean a’ Chaoil at the mouth of the loch and Eilean Cnapach at the eastern end of the south shore. Inner Loch Torridon contains several intertidal zones, the most extensive being at the head of the loch. The area has several small settlements along its coast line. At the head of the loch lies Torridon village along with three other main settlements of Inveralligin on the north shore and Annat and Balgy located on the south shore

Coordinates for the middle of Inner Loch Torridon:

57° 32.67’ N 005° 35.14’ W
NG 85521 56164

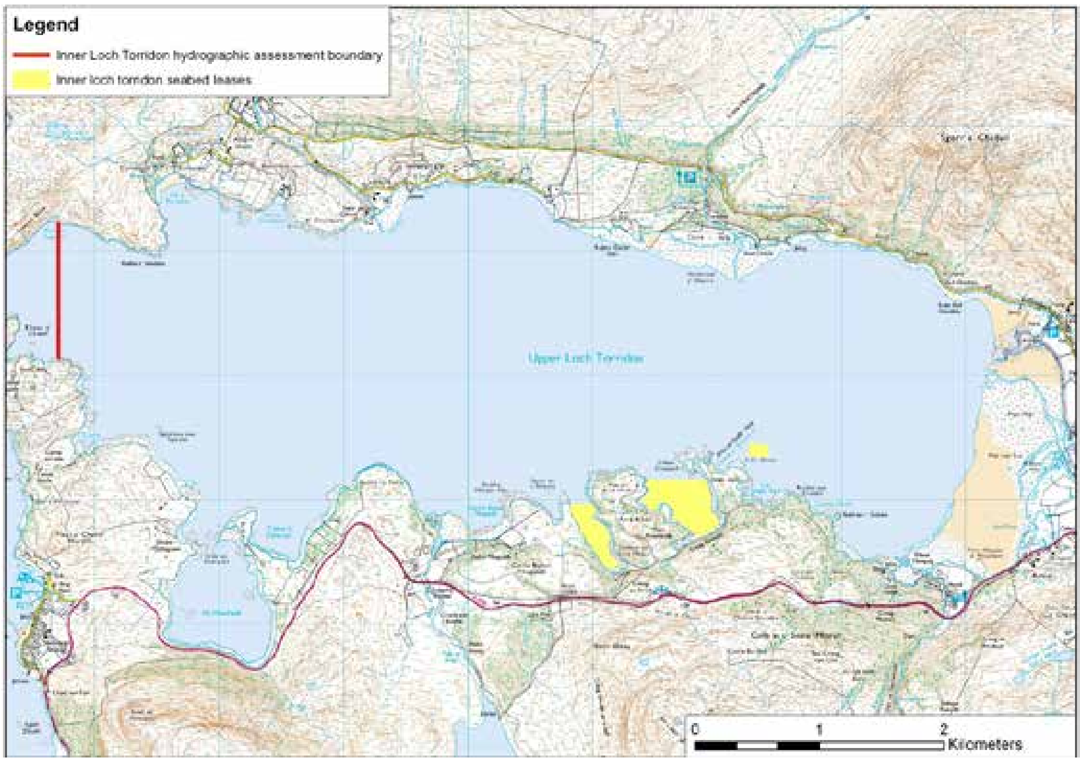

Figure 13.1 Extent of hydrographic study area

13.2 Bathymetry and Hydrodynamics

13.2.1 Bathymetry

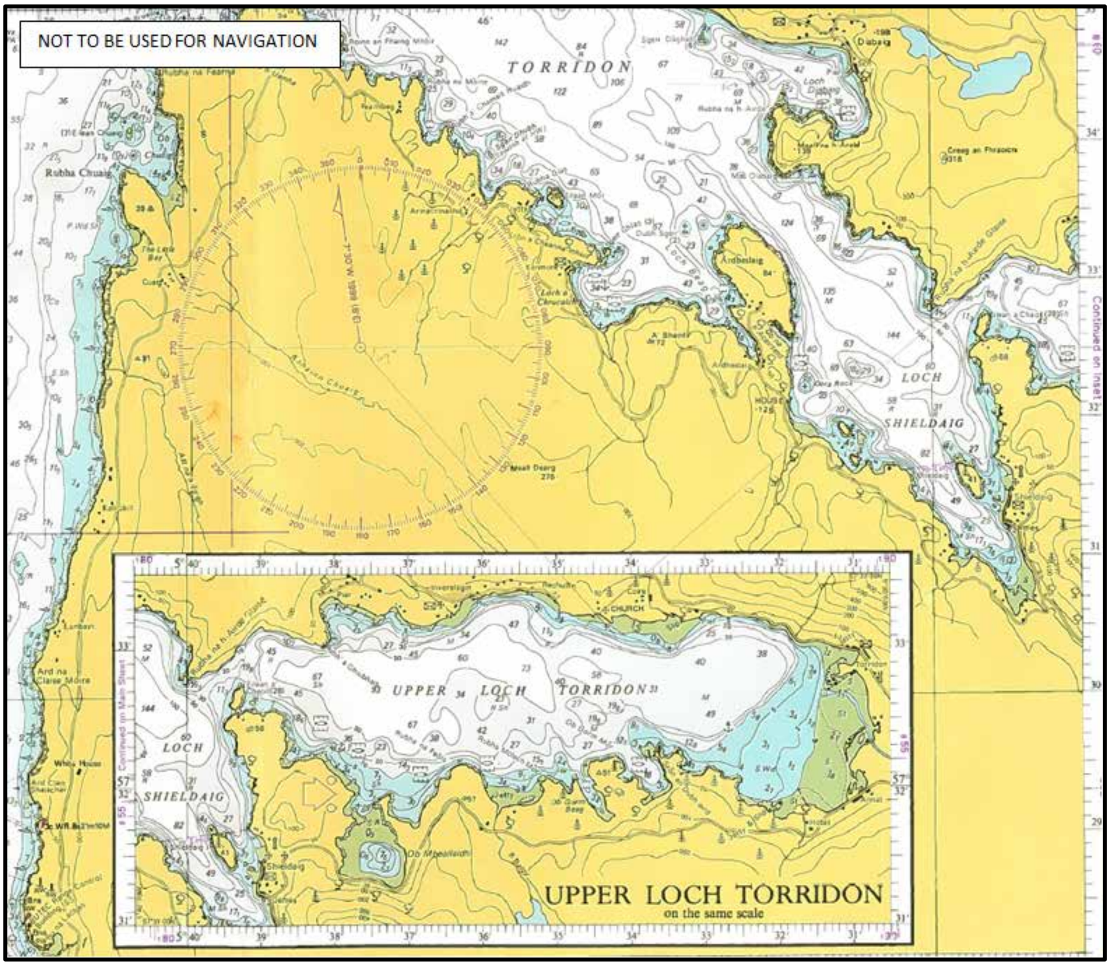

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Figure 13.2 Admiralty chart (2210) extract for Inner (Upper) Loch Torridon..

Figure 13.2 shows the bathymetry of Inner Loch Torridon. The outer loch has an axis that is predominantly northwest facing but the Inner loch has an east-west axis. The Inner part is fairly sheltered from the west due to the headland at Eilean a' Chaoil which points northward and forms a natural, partial barrier at the entrance. The entire Torridon loch system is 22.2 km in length with a mean width of 3.2 km and an estimated mean low water depth of 57.5 m (Edwards & Sharples, 1986). Therefore the estimated low water volume is approximately 4.0 x 10^9 m^3 which makes Loch Torridon second only to Loch Fyne in terms of highest volumetric capacity in a Scottish sea loch. Inner Loch Torridon is approximately 8.5 km in length with the maximum depth from Admiralty Chart 2210 specified as 73 m although Gillibrand and Amumdrud (2007) state that it is 93 m. The high water surface area of the inner part is calculated at 20 km^2 which is 15% of the entire loch area. There is a sill at the narrows between Loch Shieldaig and Inner Loch Torridon, one of three sills in the whole loch complex, having a maximum depth of 20 m (Edwards & Sharples, 1986; Gillibrand & Amundrud, 2007).

13.2.2 Tides

Loch Torridon has a typical semi-diurnal tidal characteristic with a clear spring-neap cycle (Gillibrand & Amundrud, 2007). Data on tidal information is given from charted information. The nearest location for tidal predictions is Shieldaig [http://easytide.ukho.gov.uk].

Standard tidal data for Shieldaig, Loch Torridon are given below (from Admiralty Surveys) and the spring/neap cycle of tidal height around the time of the planned survey (26 – 27th August 2013) is shown in figure 13.3:

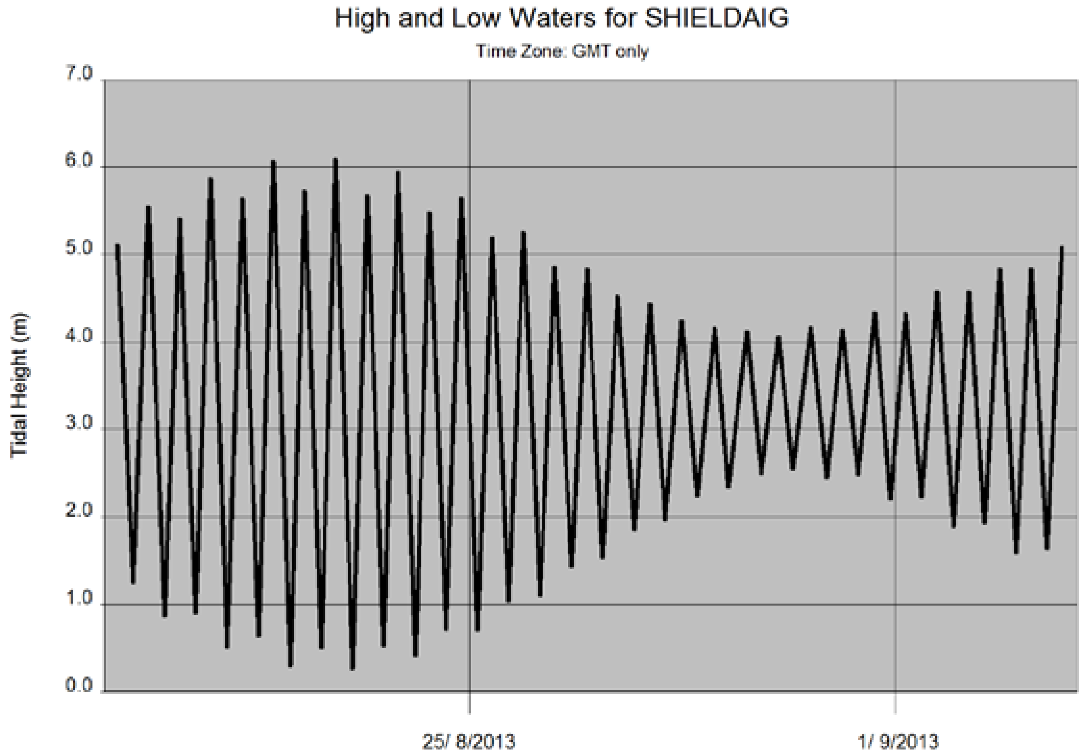

Figure 13.3 Two week tidal curve for Shieldaig, Loch Torridon. Reproduced from Poltips3 [www.pol.ac.uk/appl/poltips3]

Tidal Heights at Shieldaig, Loch Torridon:

Mean High Water Springs = 5.6 m
Mean Low Water Springs = 0.7 m
Mean High Water Neaps = 4.2 m
Mean Low Water Neaps = 2.2 m

Tidal Ranges:
Mean Spring Range = 4.9 m
Mean Neap Range = 2.0 m

This gives a volume of water exchanged in the inner part during each tidal cycle of approximately:
Springs: $1 \times 10^8\ m^3$
Neaps: $4 \times 10^7\ m^3$

13.2.3 Tidal Streams and Currents

There are no published tidal diamonds for this area. Enhancement of tidal streams caused by straights and shallow channels will be important at the narrows between Inner Loch Torridon and Loch Shieldaig. Otherwise, there are no morphological features within the main body of Inner Loch Torridon that might cause enhanced tidal flow.

There are current meter data available from three previous surveys. Current data were obtained from SEPA which were collected from the same site within Inner Loch Torridon but in different years with surveys in February 2003 (Marine Harvest, 2003), November 2005 (Marine Harvest, 2006) and August 2009 (Marine Harvest, 2011). Figure 13.4 shows the location of this site. The Hydrographic surveys typically span 15 days; being the half-lunar period to capture a spring-neap cycle.

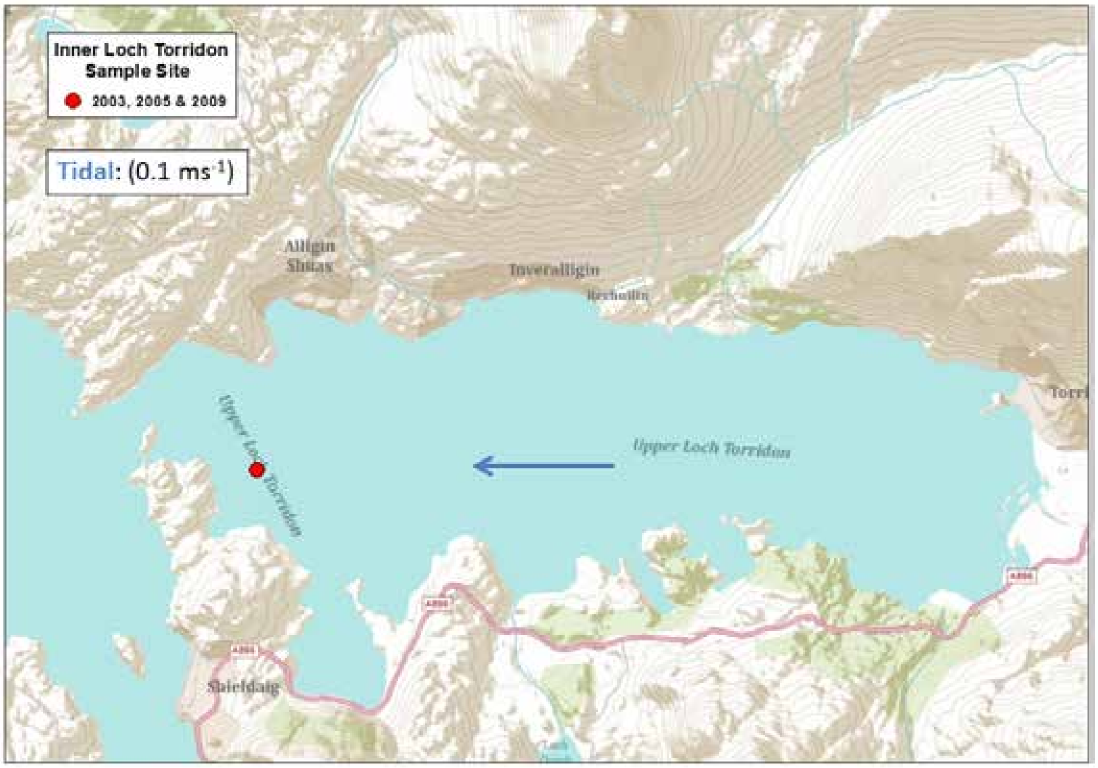

Figure 13.4 Map showing Inner Loch Torridon sample site. Net cumulative displacement through tidal flow (ebb) is shown.

Data from 21st February to 10th March 2003 (Marine Harvest, 2003) were collected from the west of Inner Loch Torridon near the narrows joining the assessment area with Loch Shieldaig and is summarised in Table 13.1. There was considerable variability in the range of velocity measurements over the period of observations particularly in the surface layers, with the deepest layer showing predominantly semi-diurnal variation within a spring-neap cycle. Residual flows were not calculated or reported for this deployment but the cumulative flow is to the north or northwest towards the narrows indicative of a seaward residual flow. There is enhancement in the velocity in the surface layer with speeds greater than 0.2 m/s for approximately 50% of the time. There is rather little technical narrative accompanying the report for 2003 in Inner Loch Torridon and no explicit assessment from that survey of the flushing properties at that location.

Table 13.1 Inner Loch Torridon current data measured in 2003

Height above seabed	Near-bed (2.0 m)	Mid (20.2 m)	Sub-surface(32.3 m)
Mean Speed (ms^{-1})	0.067	0.076	0.193

Data from 3rd November to 18th November 2005 (Marine Harvest, 2006) were collected from the west of Inner Loch Torridon near the narrows joining the assessment area with Loch Shieldaig and is summarised in Table 13.2. Semi-diurnal periodicity along with spring-neap variation was displayed throughout the velocity readings. In general, the currents were of a moderate velocity with the slowest speeds recorded near the bed. Although the tabulated mean speed was greatest in the sub-surface there were similarities in current speeds between mid-depths and sub-surface depths. In all depths, the cumulative transport was northwest, towards the narrows at the entrance to the Inner Loch. There is rather little technical narrative accompanying the report for 2005 in Inner Loch Torridon and no assessment from that survey of the flushing properties at that location.

Table 13.2 Inner Loch Torridon current data measured in 2005

Height above seabed	Near-bed (3.7 m)	Mid (19.5 m)	Sub-surface (31.5 m)
Mean Speed (ms^{-1})	0.046	0.077	0.081
Principal Axis Amp & Dir (ms^{-1}) & (^oM)	Not given (320)	Not given (320)	0.09 (330)
Residual speed (ms^{-1})	0.023	0.048	0.052
Residual direction (^oM)	334	315	314

Data from 31st July to 15th August 2009 (Marine Harvest, 2011) were collected from the same site as the 2005 and 2003 data and is summarised in Table 13.3. Semi-diurnal periodicity along with some spring-neap variation was displayed throughout the velocity readings. In general, the currents were of a moderate velocity. However, the sub-surface current speeds showed a high mean velocity with residual flow primarily in a north-northeast direction. The mid- and near-bed current speeds showed reasonable similarity although with residual flow tending slightly to the north-west in the middle depth and north-east in the bottom depth. However, in general all depths showed similarity in direction with the current directed along the axis of the peninsula stretching out from Shieldaig. As would be expected, the current speeds increase as the water depth decreases.

Table 13.3 Inner Loch Torridon current data measured in 2009

Height above seabed	Near-bed (2.7 m)	Mid (32.2 m)	Sub-surface (43.2 m)
Mean Speed (ms^{-1})	0.069	0.087	0.109
Maximum Speed (ms^{-1})	0.234	0.228	0.400
Principal Axis Amp & Dir (ms^{-1}) & (^oM)	0.069 (320)	0.072 (335)	0.084 (350)
Residual speed (ms^{-1})	0.050	0.074	0.096
Residual direction (^oM)	004	352	015

The three data sets described above follow a similar trend; notably an enhanced current speed in the sub-surface layer compared to that near the bed. Further, although there is slight variation, there is a general trend of the principal axis and the residual to have a direction towards the north and northwest. This is a direction aligned with the underlying bathymetry and shoreline. It is also important to note that the magnitude of the surface residual flow is similar order of magnitude to speed of the main tidal flow. This may be related to the proximity of the observations to the narrows where the flow is modified considerably.

Results from a three-dimensional, hydrodynamic particle transport model, forced by tides and winds, has been reported in the literature (Gillibrand & Amundrud, 2007; Murray & Gillibrand, 2006) which simulates the flows at the narrows between Loch Shieldaig and Inner Loch Torridon. The model predicts that the flow of tidal currents are heavily influenced by the constraining nature of the shallow sill with a large acceleration of the flow throughout flood and ebb tides. During maximum flood tide the current speed in the deeper central parts of the basin is typically 0.1 m/s. In the region of the sill, this increases to 1.2 m/s.

In the deeper waters of Inner Loch Torridon, the cumulative transport that might be expected during each phase of the tide is approximately 1.3 km (plotted in figure 13.4) based on a maximum tidal current speed of 0.1 m/s. The magnitude of the residual current will be highly variable within the assessment site, and likely greatest nearest the narrows.

The particle transport model predicts a significant lateral variability in the tidal and residual circulation fields, especially in the surface waters of the loch. At the western end of Inner Loch Torridon there is a weak residual circulation (with speeds typically 0.1 m/s) which comprises an anticyclonic gyre. These may have a slightly restricting effect on the exchange of water across the sill, increasing residence time in the inner loch. The direction and magnitude of the modelled residual flow in the vicinity of the Marine Harvest surveys reported in sections 2.3.2-2.3.5 is comparable with the measured values.

The three-dimensional coastal ocean model run by Amundrud and Murray (2009) predicts that the tides within Loch Torridon have an influence in the dispersion of particles especially during spring tides where there is increased tidal mixing and therefore a greater dispersal of particles.

13.2.4 River/Freshwater Inflow

There are several freshwater inputs around the shoreline of Inner Loch Torridon which may or may not flow depending on the season. The main water course is at the head of Inner Loch Torridon where several rivers join and then exit into the loch. These rivers include the River Torridon, Allt Luib Molaich and Abhainn Thrail. On the northern shore there are two more significant freshwater inputs including Abhainn Coire MhicNobaill from the north east and Abhainn Alligin on the north west shore. The main input from the southern shore originates from Loch Damh and enters Inner Loch Torridon as the River Balgy and from the south east shore freshwater enters from Allt Coire Roill. There are other unnamed watercourses on the OS map.

The annual precipitation in the area is approximately 2000 mm and the annual freshwater runoff is estimated as 421 Mm^3yr^{-1} (Edwards & Sharples, 1986). The freshwater input into the loch complex has a low influence on the dynamics of the system with a fresh/tidal flow ratio of 1:400, giving a salinity reduction of 0.1 (SEPA, 2011).

The flow rates of freshwater input can vary considerably (Gillibrand & Amundrud, 2007) but in general, there is a greater amount entering the loch during the winter months especially December to February. However, all months in this area can experience high discharge and conversely periods of sparse run-off.

There is largely weak stratification in the loch system due to the small drainage area and the surface to bottom density discrepancy is around 1 kgm^{-3}. The loch does show greater stratification in summer (Gillibrand & Amundrud, 2007) but in general, freshwater input is not a significant influence on the properties of Loch Torridon (Murray & Gillibrand, 2006).

Under an extreme freshwater event in the model run by Amundrud and Murray (2009) in which a significant amount of freshwater is discharged into Inner Loch Torridon, the estuarine outflow in the surface layers is increased through the narrows at Loch Shieldaig and therefore particles are effectively exported from Inner Loch Torridon to Loch Shieldaig. However, this is a worst-case scenario and realistically, freshwater input is not thought to have a large effect on dispersion within Loch Torridon (Amundrud & Murray, 2009).

Salinities within the entire Loch Torridon complex are reported to be comparable to open sea water (Amundrud & Murray, 2009) with the surface densities within the study area showing a gradient along the loch axis, with density increasing towards the narrows and commensurate with the discharge of freshwater.

13.2.5 Meteorology

Rainfall data were taken from Lusa in Skye which is situated roughly 33 km to the south west of Inner Loch Torridon. These data were used rather than data from Loch Torridon as it was deemed that Torridon records were incomplete and inaccurate estimates. Records from Lusa spanned the time frame from January 2007 to August 2012.

The year with the highest rainfall was 2011 and the least rain fell in 2010. In the years 2007, 2008, 2009 and 2012, extreme rainfall levels of > 60 mm/d were recorded but generally high rainfall values (>30 mm/d) were seen in all years. The highest daily rainfall values occurred throughout winter where rainfall increased from September to January. There was rainfall of >30 mm/d in all months with the exception of June. For the duration of the data set, daily rainfall of below 1 mm occurred 40% of the time and daily rainfall of above 10 mm occurred 19% of the time.

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

Data about wind conditions were collected from Stornoway Airport which is located approximately 85 km north west of the production area on the north east coast of the Isle of Lewis. Due to the distance between the two areas, the wind rose statistics may not be directly transferrable to the specific production area in Inner Loch Torridon but they can be used to give a general picture of the seasonal wind conditions in the northwest area. The data from Stornoway shows that overall westerly winds and southerly winds were stronger than northerly or easterly winds. There is a predominant south-westerly airflow year round for the area. It is highly likely that the wind direction will be strongly influenced in Loch Torridon by the morphology of the surrounding high ground (Amundrud & Murray, 2009). From the data gathered, it can be surmised that Inner Loch Torridon may be relatively sheltered from prevailing winds.

Results from numerical models for the area show that particle motion is strongly influenced by winds (Amundrud & Murray, 2009; Murray & Gillibrand, 2006). They show that, under conditions of wind from the eastern quadrant, particles can be transported from Inner Loch Torridon to beyond the narrows at Loch Shieldaig. They state in a caveat that there must be peak strong wind conditions for there to be a significant transport of particles.

A meteorological survey was completed in a location in Inner Loch Torridon (see figure 13.4 for location) by Marine Harvest is summarised below in Table 13.4 (Marine Harvest, 2011)

During the length of data accumulation in this area, the wind speeds were comparatively low and overall meteorological conditions appear not to have had any consequence on the surface current speed and direction. Whilst the wind was primarily from the north, the current was predominantly flowing in a northerly direction (Marine Harvest, 2011).

Table 13.4 Inner Loch Torridon wind speed data

Measurement date	2009 (15 day period)
Mean Speed (ms^{-1})	3.5
Maximum Speed (ms^{-1})	5.9
Minimum Speed (ms^{-1})	1.3

13.2.6 Model Assessment

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

The box model quantifies the primary exchange mechanisms. The key outputs from the model with respect to this hydrographic assessment are a series of annual mean values that describe the relative importance of the estuarine (gravity) exchange, tidal exchange, exchange between the layers and the flushing time (inverse of the exchange rate) of the surface and intermediate layers. These values are given in Table 13.5

Table 13.5 Summary of annual mean parameter values from the box modelling exercise.

Parameter	Value
Tidal Volume Flux (m^3 s^{-1})	5493.3
Estuarine Circulation Volume Flux (m^3 s^{-1})	122.4
Wind Driven Entrainment between upper and lower layer (m^3 s^{-1})	191.6
Tidal and Density driven entrainment between upper and lower layers (m^3 s^{-1})	2.6
Median Flushing Time (days)	7.1
95%-ile Flushing Time (days)	12.8

The ratio of tidal volume flux to estuarine circulation volume flux is 44.8. Values greater than 2 indicate a system that is strongly tidal in its exchange characteristics (Gillibrand, *et al.*, 2013).

The flushing time for Loch Torridon is estimated at around 7 days which is slightly less than the value for the simplified tidal prism model of 9 days (Edwards & Sharples, 1986).

13.3 Hydrographic Assessment

13.3.1 Surface Flow

The surface current at the SEPA measurement locations is in a predominantly northerly direction and the weak wind forcing during the measurement periods did appear not to have a large influence in Inner Loch Torridon (Marine Harvest, 2011).

Tidal flow in the inner basin has been estimated to transport particles around 1.3 km based on a peak tidal flow of 0.1 m/s. Residual flow near the narrows is shown to be a similar order of magnitude.

However, Murray and Gillibrand (2006) state that the surface layer currents are 'strongly influenced' by meteorological factors and in the case of Inner Loch Torridon winds from the eastern quarter will enhance transport and dispersion of surface waters. This model is also using optimum wind conditions and therefore is a 'worst-case' scenario. In some cases of strong westerly wind, the wind forcing can reverse the direction of the tidal flow, indicating that strong winds can generate a surface flow in excess of 0.1 ms^{-1}.

The site and the meteorological data indicate that there is likely to be a rather small freshwater discharge into the surface waters of the loch. There seems to be a consensus on this throughout the various reports used in this survey. It must be noted however that the absolute value of discharge would have moderate seasonal variation. Stratification is weak and typically only in summer months.

Surface flows would be enhanced/retarded by winds blowing out of/into the loch. The winds would be generally funnelled by the surrounding hills creating winds blowing along the axis of the loch which would further enhance the mixing of the waters through the full depth.

In summary the surface circulation in Loch Torridon is primarily driven by tides and enhanced by wind forcing with rather weak estuarine circulation.

13.3.2 Exchange Properties

The flushing time for the whole loch complex using a simple tidal prism approach is 9 days but this can vary due to each separate basin having different characteristics with the deeper waters being exchanged at a considerably slower rate than moderate to shallower depths (SEPA, 2011).

Data collected by Murray and Gillibrand (2006) show that the exchange properties are typically fjordic. There is an overall net flow in a seaward direction of the surface waters, which are thus likely to experience the shortest flushing times compared to the deeper basin waters.

Exchange and residence times may be influenced by the weak residual currents in the middle basin that are created by the accelerated flow during flood and ebb tides setting up weak anticyclonic gyres (Gillibrand & Amundrud, 2007).

The key aspect of the model output in terms of the exchange is that the tidal volume flux dominates the estuarine (or gravitational) volume flux by a factor of 44.8. This means that exchange of waters in Loch Torridon is principally a tidally driven process. Hence there is likely to be rather little seasonal variation in the flushing time of the Loch. The model predicts that 95% of the time the flushing time will be 13 days or less which is a fairly typically value. Most Scottish sea lochs have a flushing time of less than 20 days.

There is a relatively good data series available for Inner Loch Torridon and there is considerable numerical modelling effort in this region. Consequently, we are able to determine some of the broad features of the loch circulation, though the details of seasonality are not easily inferred. Therefore the confidence level of this assessment is HIGH.

14. Shoreline Survey Overview

The shoreline survey at Inner Loch Torridon was conducted on the 26th and 27th August 2013. The weather was mostly sunny, with only light rain recorded on the morning of the second day. No rain fell in the 48 hrs prior to the survey.

The Inner Loch Torridon fishery consisted of three common mussel farms; Ob Gorm Beag, Ob Gorm Mor and Dubh Aird. Each farm was located within a separate sheltered natural inlet along the southern shore. Cultivation is via long-lines, with three lines present at each site. Polystyrene floats are used at Ob Gorm Beag, Ob Gorm Mor, with large plastic floats used at Dubh Aird.

Mr J.C. MacDonald owns both Ob Gorm Beag and Ob Gorm Mor farms. These were found to be in a poor state with the sampling officer identifying that both sites had not been active for some time. Stock consisted of very large, mature mussels and no plans were in place to alter the current setup. Mussel samples taken at Ob Gorm Beag and Ob Gorm Mor farms returned results of 20 *E. coli* MPN/100 g or less. The only seawater sample which yielded a result above the limit of detection of the test was taken to the southern extent of Ob Gorm Beag: the result was 3 *E. coli* cfu/100 ml. All other seawater samples returned results of 0 *E. coli* cfu/100 ml.

Mr Kenneth MacGregor owns the Dubh Aird site, where stock consisted of mostly mature mussels. Mr MacGregor also indicated that two of the lines had recently been deployed for spat settlement. A mussel sample taken at the western extent of the northern line returned a result of 170 *E. coli* MPN/100 g, whilst a seawater sample returned a result of 0 *E. coli* cfu/100 ml.

The shores around Inner Loch Torridon are sparsely populated. The population is mostly centred in villages of Inveralligin and Torridon, with some houses outside these settlements along the northeast shore. A seawater sample taken adjacent to the Torridon Fasaig ST returned a result of 3 *E. coli* cfu/100 ml, whilst a second seawater sample taken adjacent to a ST associated with a fish farm shore base at Shieldaig returned a result of 0 *E. coli* cfu/100 ml. Several seasonal letting properties were noted along the southeast shore, close to Torridon Hotel. An official campsite was noted close to the National Trust for Scotland Visitor Centre (east shore) and remnants of a wild camping site were noted at Inveralligin. One jetty was observed west of Torridon village and four unoccupied moorings were observed adjacent to the fish farm shore base at Shieldaig.

No livestock were observed during the survey, though sheep droppings were seen around Balgy Bridge. Small areas of improved grazing land were also present around Torridon village, and crofted land was also present around Inveralligin.

Areas of native and plantation forestry were noted along north and south shores, with areas of native woodland also noted around Torridon. Torridon House has associated gardens, and areas of rhododendron bushes and moorland were also present on the south shore.

Several large rivers enter into Inner Loch Torridon, with numerous smaller watercourses also noted during the survey. All recorded watercourses had low contamination levels of 10 or <10 *E. coli* cfu/100 ml.

No wildlife was observed during the survey.

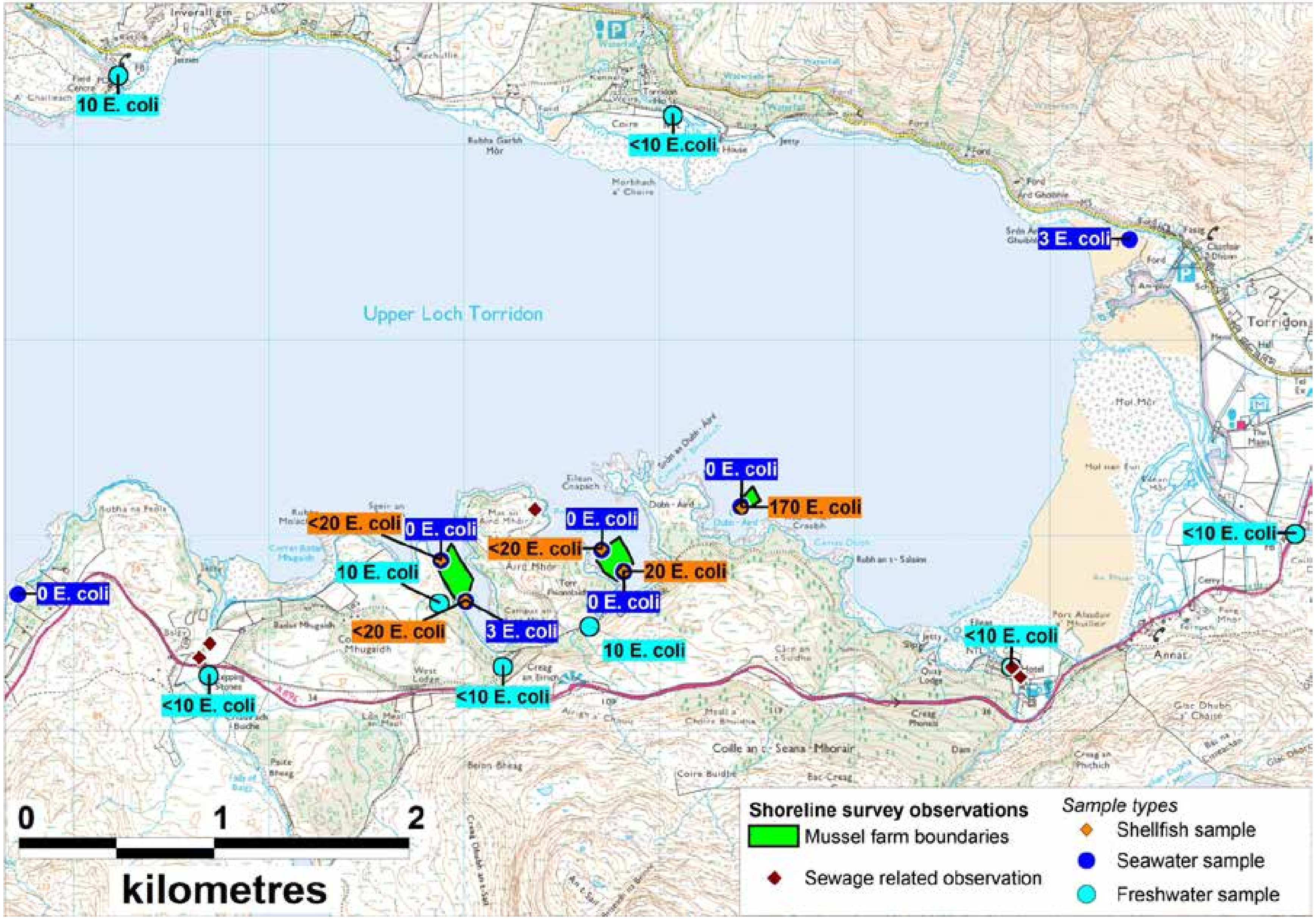

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Figure 14.1 Map of shoreline survey observations at Inner Loch Torridon

15. Bacteriological Survey

No bacteriological survey was undertaken for Inner Loch Torridon as it was assessed that the principal sources of pollution were adequately identified during the desk study and shoreline survey.

16. Overall Assessment

Human sewage impacts

There are two community discharges in the area. The most significant of these with regard to the fisheries is the septic tank at Torridon, which has a population equivalent of 190. In addition, there are a number of private septic tank discharges in the vicinity of Torridon and Inverallign. There is also a large private septic tank associate with the Torridon Hotel, which lies approximately 1.6 km southeast of the Dubh Aird mussel farm.

Discharges from private septic tanks and public water treatment works associated with properties at Torridon and private septic tanks at Inverallign are nearest to the mussel lines. Most of the impact will be via diffuse runoff rather than direct discharge to sea. One septic tank, discharging to soakaway, was observed during the shoreline survey at the head of Aird Mhor peninsular adjacent to Ob Gorm Mor.

Boats using the anchorages in the vicinity of the mussel farms could cause significant local contamination if faecal material was disposed overboard.

Agricultural impacts

Any contamination associated with agricultural sources is likely to be associated with the croft areas at the head of the loch, including that associated with sheep grazing at that location.

Wildlife impacts

No wildlife was recorded during the shoreline survey although anecdotal sources do refer to the presence of seals, cetaceans, birds, deer and otters in the area. No significant populations of any of these were identified. It is therefore assumed that any impact from this source is unpredictable both spatially and temporally.

Seasonal variation

There is some holiday accommodation in the vicinity of Inner Loch Torridon and this will result in an increase in faecal loading from sewage discharges in the area. The season can extend from April to October although occupancy would be expected to be highest from July to August.

Rainfall-associated land runoff will be higher during the autumn and winter months although extreme rainfall events leading to episodes of high runoff can occur in most months.

A statistically significant difference was found between *E. coli* results by season with those in summer higher than those in spring and winter.

Watercourses

At the time of the shoreline survey, contamination levels in all of the watercourses were very low. It is expected that this would be greater after rainfall and that, if so, the watercourses of principal significance to the fisheries would be those at the head of the loch and also the small watercourses within Ob Gorm Beag and Ob Gorm Mor.

Movement of contaminants

Particle transport associated with tidal flow in the inner basin of Loch Torridon was estimated to be in the order of 1.3 km based on a peak tidal flow of 0.1 m/s. Surface layer currents may be influenced by winds, enhancing flows when the wind is from the east and reducing, or even reversing flows when the wind is from the west.

Temporal and geographical patterns of sampling results

Historical shellfish results

There has been no marked change in *E. coli* results over time. It is difficult to assess any spatial variation as most of the samples have been reported against locations on the southern end of Ob Gorm Mor and it is not clear how these samples relate to the mussel farm at that site.

Shoreline survey results

During the shoreline survey, mussel samples were taken at five locations, two at Ob Gorm Beag, two at Ob Gorm Mor and one at Dubh Aird. The depth at which the mussel samples were taken was not recorded. The results were all <20 or 20 *E. coli* MPN/100 g, except for the sample taken at Dubh Aird which gave a results of 170 *E. coli/*100 g.

Seven seawater samples were also taken during the shoreline survey. The highest results were both 3 *E. coli* cfu/100 ml, seen at one location within Ob Gorm Beag and another at the northern end of the intertidal area at Torridon. Even these results are low compared to the range often seen during shoreline surveys in Scotland.

Conclusions

Most of the identified sources of contamination lie around the head of the loch although there are some private sewage discharges and watercourses on the northern shore and a small number to the west of Ob Gorm Beag. There is some potential for additional localised sources of contamination in the vicinity of the separate mussel sites.

17. Recommendations

Production area

It is recommended that the extent of the production area be reduced in order to exclude the main identified sources of contamination. It is therefore recommended that it be redefined as: "the area within lines drawn between NG 8542 5501 and NG 8542 5600 and between NG 8542 5600 and NG 8796 5600 and between NG 8796 5600 and NG 8796 5489, and extending to mean high water springs (MHWS).

RMP

During the consultation on the draft survey report, the local authority identified that it was not possible to obtain samples from the mussel lines due to the ad hoc presence of the harvester and therefore requested that an RMP be established on the intertidal shoreline, where access would be possible on a more regular basis.

It is therefore recommended that the representative monitoring point be located at NG 8752 5502, to the south of the Dubh Aird site, in order to reflect the main sources of contamination identified in the area.

However, it should be noted that in past surveys where monitoring results were available from both shore mussels at the intertidal zone and at suspended mussel culture sites, the bacteriological results from shore mussels were 1-2 magnitudes higher than those seen at the suspended culture sites. This is thought to be due to proximity to land-based sources of contamination and to the more limited opportunity for dilution at the intertidal zone.

Tolerance

It is recommended that a tolerance of 75 m be applied to allow sufficient scope to obtain shore mussels for sampling purposes.

Depth of sampling

No depth is applicable due to the intertidal location of the monitoring point.

Frequency

It is recommended that monthly monitoring be continued given that a significant seasonal effect has been identified in the area.

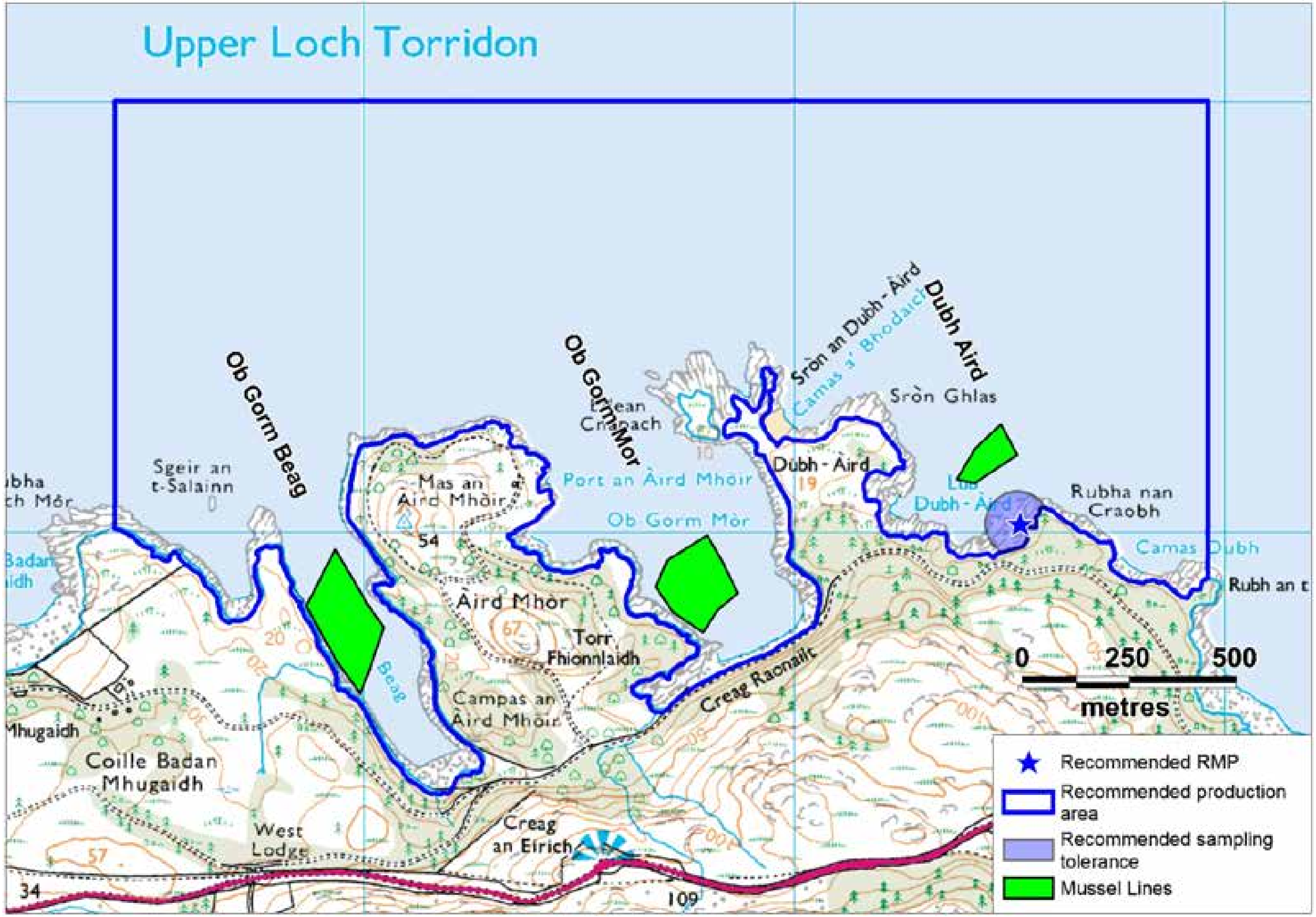

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Figure 17.1 Map of recommendations at Inner Loch Torridon

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19. List of Figures and Tables

Appendices

1. **General Information on Wildlife Impacts**
2. **Tables of Typical Faecal Bacteria Concentrations**
3. **Statistical Data**
4. **Hydrographic Section Glossary**
5. **Shoreline Survey Report**
6. **SEPA Discharge Consents**
7. **CTD Data**

1. General Information on Wildlife Impacts

Pinnipeds

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

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

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

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

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

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

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

Cetaceans

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

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

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

Birds

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

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

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

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

Deer

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

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

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

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

Other

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

Otters leave faeces (also known as spraint) along the shore 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	$1.7 \times 10^{7*}$ (+)	1.4×10^7	2.0×10^7	282	$2.8 \times 10^{6*}$ (-)	2.3×10^6	3.2×10^6
Crude sewage discharges	252	$1.7 \times 10^{7*}$ (+)	1.4×10^7	2.0×10^7	79	$3.5 \times 10^{6*}$ (-)	2.6×10^6	4.7×10^6
Storm sewage overflows					203	2.5×10^6	2.0×10^6	2.9×10^6
Primary	127	$1.0 \times 10^{7*}$ (+)	8.4×10^6	1.3×10^7	14	4.6×10^6 (-)	2.1×10^6	1.0×10^7
Primary settled sewage	60	1.8×10^7	1.4×10^7	2.1×10^7	8	5.7×10^6		
Stored settled sewage	25	5.6×10^6	3.2×10^6	9.7×10^6	1	8.0×10^5		
Settled septic tank	42	7.2×10^6	4.4×10^6	1.1×10^7	5	4.8×10^6		
Secondary	864	$3.3 \times 10^{5*}$ (-)	2.9×10^5	3.7×10^5	184	$5.0 \times 10^{5*}$ (+)	3.7×10^5	6.8×10^5
Trickling filter	477	4.3×10^5	3.6×10^5	5.0×10^5	76	5.5×10^5	3.8×10^5	8.0×10^5
Activated sludge	261	$2.8 \times 10^{5*}$ (-)	2.2×10^5	3.5×10^5	93	$5.1 \times 10^{5*}$ (+)	3.1×10^5	8.5×10^5
Oxidation ditch	35	2.0×10^5	1.1×10^5	3.7×10^5	5	5.6×10^5		
Trickling/sand filter	11	2.1×10^5	9.0×10^4	6.0×10^5	8	1.3×10^5		
Rotating biological contactor	80	1.6×10^5	1.1×10^5	2.3×10^5	2	6.7×10^5		
Tertiary	179	1.3×10^3	7.5×10^2	2.2×10^3	8	9.1×10^2		
Reed bed/grass plot	71	1.3×10^4	5.4×10^3	3.4×10^4	2	1.5×10^4		
Ultraviolet disinfection	108	2.8×10^2	1.7×10^2	4.4×10^2	6	3.6×10^2		

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

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3. Statistical Data

One-way ANOVA: logec versus season

```
Source DF   SS   MS   F   P

season  3  8.116 2.705 4.83 0.004

Error  65 36.423 0.560

Total  68 44.539

S = 0.7486  R-Sq = 18.22%  R-Sq(adj) = 14.45%

              Individual 95% CIs For Mean Based on

              Pooled StDev

Level  N  Mean  StDev -----+---------+---------+---------+----

1   18 1.3489 0.6541 (--------*--------)

2   19 2.1235 0.9948           (-------*--------)

3   16 1.8911 0.7310        (--------*---------)

4   16 1.3542 0.4706 (--------*--------)

              -----+---------+---------+---------+----

               1.20   1.60   2.00   2.40

Pooled StDev = 0.7486

Grouping Information Using Tukey Method

season  N  Mean Grouping

2    19 2.1235 A

3    16 1.8911 A B

4    16 1.3542  B

1    18 1.3489  B

Means that do not share a letter are significantly different.

Tukey 95% Simultaneous Confidence Intervals

All Pairwise Comparisons among Levels of season

Individual confidence level = 98.96%

season = 1 subtracted from:

season  Lower Center  Upper --------+---------+---------+---------+-

2    0.1252 0.7746 1.4240           (-------*-------)

3    -0.1362 0.5422 1.2206         (--------*-------)
```

```
4    -0.6731 0.0053 0.6837      (-------*--------)

                 --------+---------+---------+---------+-

                   -0.80   0.00   0.80   1.60

season = 2 subtracted from:

season  Lower  Center  Upper --------+---------+---------+---------+-

3    -0.9023 -0.2324  0.4376     (-------*-------)

4    -1.4392 -0.7693 -0.0994 (-------*--------)

                  --------+---------+---------+---------+-

                    -0.80   0.00   0.80   1.60

season = 3 subtracted from:

season  Lower  Center  Upper --------+---------+---------+---------+-

4    -1.2350 -0.5369 0.1611   (-------*--------)

                 --------+---------+---------+---------+-

                    -0.80   0.00   0.80   1.60
```

One-way ANOVA: logec versus site

```
Source DF   SS   MS   F   P

site   1  1.459 1.459 2.26 0.137

Error  66 42.598 0.645

Total  67 44.057

S = 0.8034  R-Sq = 3.31%  R-Sq(adj) = 1.85%

              Individual 95% CIs For Mean Based on Pooled StDev

Level  N  Mean  StDev  +---------+---------+---------+---------

1   37 1.8334 0.9500         (---------*----------)

3   31 1.5393 0.5805  (-----------*----------)

               +---------+---------+---------+---------

              1.25   1.50   1.75   2.00

Pooled StDev = 0.8034

Grouping Information Using Tukey Method

site  N  Mean Grouping

1   37 1.8334 A

3   31 1.5393 A
```

Means that do not share a letter are significantly different.

Tukey 95% Simultaneous Confidence Intervals

All Pairwise Comparisons among Levels of site

Individual confidence level = 95.00%

site = 1 subtracted from:

```
site  Lower  Center  Upper ---+---------+---------+---------+------
3   -0.6847 -0.2941 0.0964 (------------*------------)
                ---+---------+---------+---------+------
                -0.60   -0.30   0.00   0.30
```

4. Hydrographic Assessment Glossary

The following technical terms may appear in the hydrographic assessment.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5. Shoreline Survey Report

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

Document Number	B0067_Shoreline 0020

Revision History

Revision	Changes	Date
A	Issue for internal review	18/09/2013
01	First formal issue to CEFAS	20/09/2013
02	Second issue to Cefas incorporating comments at Rev 01	03/10/2013
03	Third issue to Cefas with corrections from Sampling Officer on site naming	18/03/2014
04	Fourth issue to client incorporating comments in issue 03	18/03/2014

	Name & Position	Date
Author	Lars Brunner & Peter Lamont	29/08/2013
Checked	Andrea Veszelovszki, John Hausrath	18/03/2014
Approved	Andrea Veszelovszki	18/03/2014

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Shoreline Survey Report

Production area:	Inner Loch Torridon
Site names:	Camas a Chlarsair (defunct) Ob Gorm Mor Rubha na Feola (out of use) Ob Gorm Beag Dubh Aird
SIN:	RC-090-806-08 RC-090-245-08 RC-090-246-08 RC-090-1617-08 RC-090-1616-08
Species:	Common Mussel (*Mytilus edulis*)
Harvester:	Mr J.C. MacDonald & Mr Kenneth MacGregor
Local Authority:	Highland Council – Ross & Cromarty
Status:	Review
Date Surveyed:	26th & 27th August 2013
Surveyed by:	Lars Brunner, Peter Lamont
Existing RMP:	NG 8697 5502
Area Surveyed:	Shoreline survey of southern shore of Inner Loch Torridon, along with isolated samples around the inner Loch.

Weather

No precipitation recorded in previous 48 hrs.

26th August: 25% cloud cover, wind S, F 3-4 with gusts, clear & dry with sunny spells later. Sea state: 3 - slight.

27th August: 100% cloud over, wind S, F 2 with occasional gusts. Intermittent light rain, clearing later with sunny spells. Sea state:3 - slight.

Stakeholder engagement during the survey

Neither Mr J.C. MacDonald or Mr MacGregor were available during the survey, but were both very helpful and provided information about the state of the fishery in the run-up to the survey by phone and e-mail.
Local sampling officers Mr Bill Steven and Mr Hamish Spence were both very helpful and provided information both prior and during the survey.

On the 26th of August the survey team met with Mr Hamish Spence, who provided additional information about the background to the fishery in the Loch, and to the general state of the loch.

Fishery

The fishery in Loch Torridon consists entirely of common mussel (*Mytilus edulis*) cultivation on long lines. The fishery occurs in three 'inlets' on the southern shore of the loch. In each 'inlet' there are three sets of lines with mature mussels, with the lines showing large and very large mussels, interspersed with a recent spat settlement.

The lines owned by Mr J.C. MacDonald in Ob Gorm Beag (RC-090-1617-08) and Ob Gorm Mor (RC-090-245-08) consist of older-style polystyrene floats strung across each bay from the west to the east side. When met on site Mr Hamish Spence confirmed that these sites had not been worked actively for some time, and consisted solely of mature mussels. This is observed in the fact that many of the polystyrene floats are in a poor state of repair, and the mussels that are present on the site are very mature, with a recent settlement of spat. As the two sites have not been harvested for some time, there was no seasonality to the use of the lines. There do not appear to be any immediate plans to change the lines, or their set-up.

Out of the three sites owned by Mr Kenneth MacGregor only one at Dubh Aird (RC-090-1616-08) is active and the other two sites, Camas a Chlarsair (RC-090-806-08) and Rhuba na Feola (RC-090-246-08) are both out of use, with Rhuba na Feola has been out of use since 2007 (information gathered from Sampling Officer). The lines at the active Dubh Aird site are formed of larger plastic mussel floats. The shellfish observed at Dubh Aird while collecting samples were mature mussels, although the harvester stated, that two of the lines were recent additions placed there for mussel spat settlement.

Sewage Sources

The shores of Inner Loch Torridon are sparsely inhabited, with population centres in the villages of Inveralligin and Torridon in the survey area, and Sheildaig in the immediate vicinity. There are also dispersed houses throughout the survey area, although there is a greater concentration of these towards the north and east of the inner loch. No discharges were observed on the shoreline walk along the southern section of the loch, nor at the individual sampling points visited on the northern and eastern parts of the shoreline.

Seasonal Population

The Torridon area is a popular tourist destination. Several seasonal letting properties were noted in the vicinity of Torridon House (NG 8707 5718) and in the grounds of Torridon Hotel (NG 8890 5411) and it is likely that there are more in the survey area. A campsite was noted beside the National Trust for Scotland Visitor Centre at location NG 9044 5584, and also in the village of Inveralligin at location NG 8404 5753.

Boats/Shipping

The only fixed jetty seen on the survey was to the west of Torridon village at NG 8945 5654, it only appeared to be suitable for use during high tides. No mooring buoys were seen at Inveralligin while on survey, although no access was made to the shore and thus not all of the area could be viewed from the survey locations. No fixed moorings were observed during the shoreline survey on the southern part of the inner loch. Although outside the immediate shoreline survey area, there was a fish farm shore base at NG 8370 5469 with four moorings visible – at the time of survey no boats were present on site.

Farming and Livestock

No livestock were observed during the survey – either on the north of the inner loch while driving between sampling sites, or while walking the shoreline on the south side. Evidence of the presence of sheep was seen at Balgy Bridge (NG 8467 5434) in the form of sheep droppings, but no livestock was observed.

Land Use

On the northern side of the inner loch, the land is largely wild, with a mixture of native and plantation forestry of various ages. Around the village of Inveralligin there is some improved crofting land, and the area around Torridon House has woodland and some improved ground as gardens. Around the village of Torridon there are small areas of improved grazing and native woodland. On the southern shore of the inner loch to the west of Torridon Hotel, the ground appears ungrazed with open moorland and cover of native woodland some of which appears to be deliberate planting. In many areas there is very thick *Rhodedendrum ponticum*.

Land Cover

Land cover seen on the survey closely followed the observed land use on the survey – On the north side of the inner loch the cover consisted of a mixture of woodland (native and forestry plantation) and small areas of improved grassland by the shore. Towards Torridon village the moorland changed to small areas of agricultural grassland with areas of heath in between. On the southern shore of the loch to the west of Torridon Hotel, the ground was a mixture, nearer the shore consisting of very thick *Rhodedendrum ponticum* thickets mixed with areas of native woodland, with open moorland on the higher levels, and some small areas of improved grassland around Balgy Bridge.

Watercourses

Numerous watercourses enter Loch Torridon, the largest of which is the River Torridon, which enters Loch Torridon at grid reference NG 8953 5514. Other larger rivers included the Abhainn Coire Mhic Nobuil at NG 8714 5709 and the Abhainn Alligin at NG 8423 5728 and the River Balgy at NG 8471 5453. Numerous smaller streams entered the Loch at various points and these are noted in the shoreline observations in Table 1.

20. Wildlife/Birds

No wildlife was observed directly during the survey. No birds were noted in the loch while on the water, and no wildlife was observed directly while on the survey route.

Shoreline Survey Maps

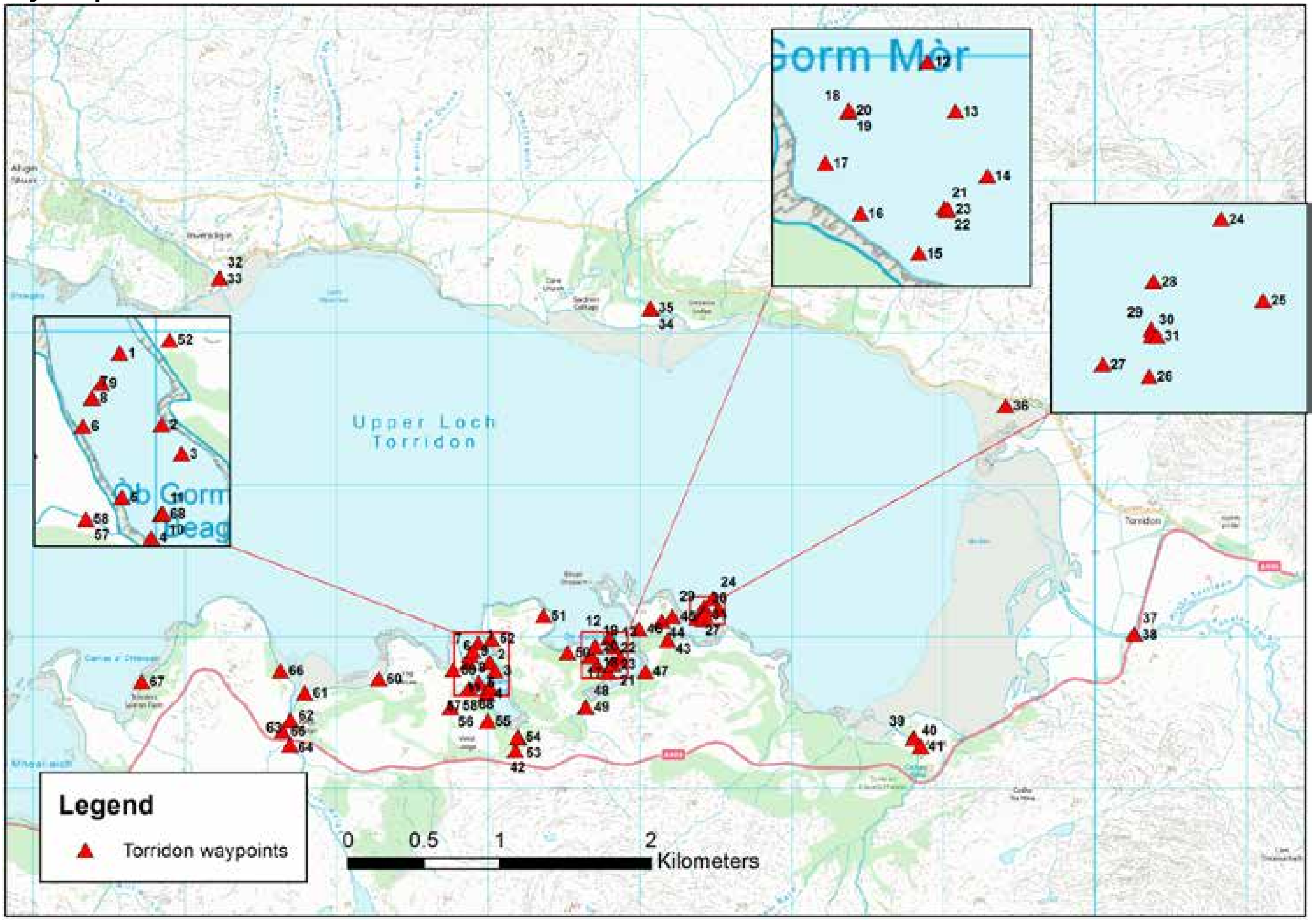

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Figure 1. Loch Torridon waypoints

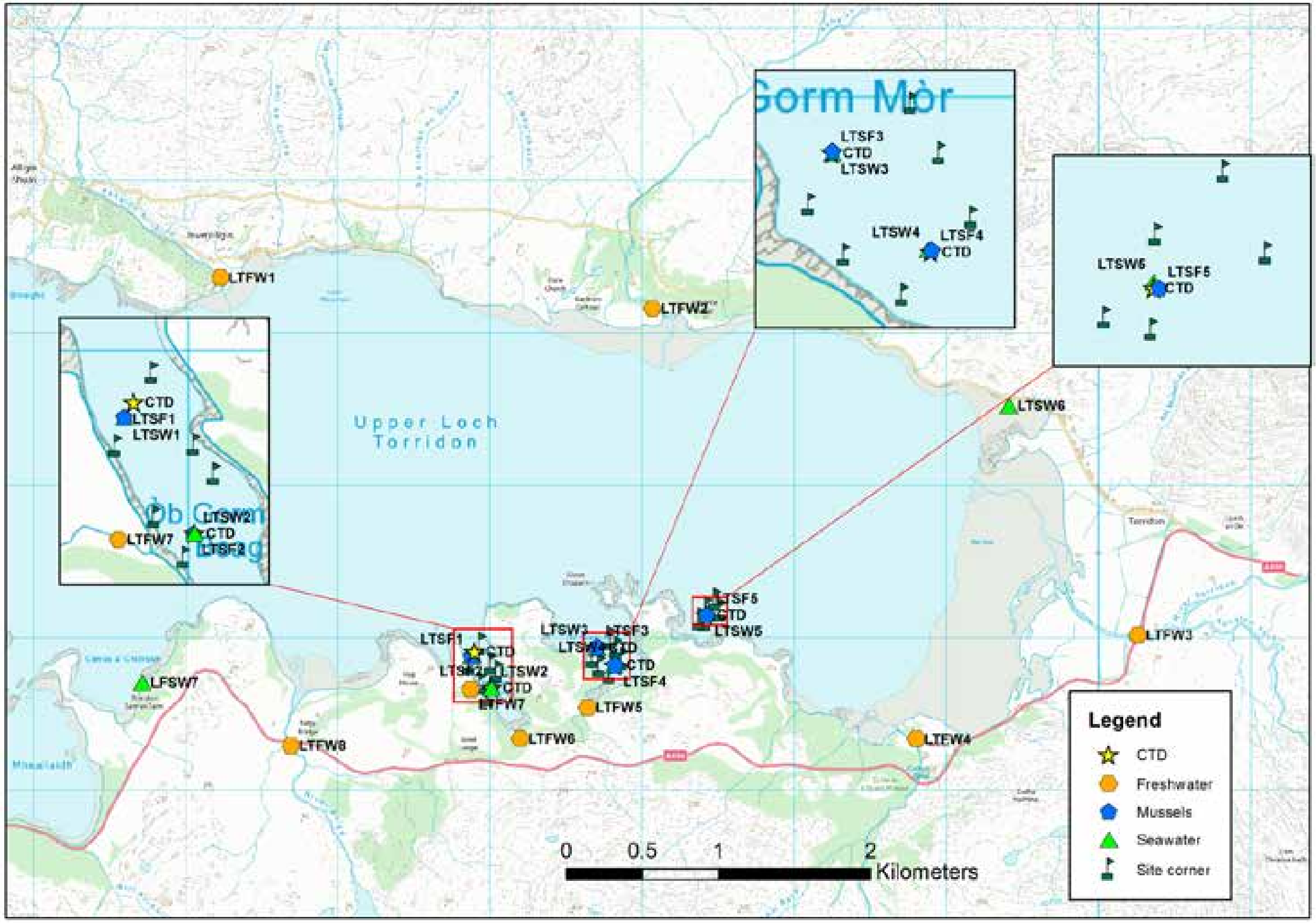

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Figure 2. Loch Torridon Samples

Table 1 Shoreline Survey Observations

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
1	26/08/2013	10:37	NG 85934 54960	185934	854961			Ob Gorm Beag, NE corner of mussel lines.
2	26/08/2013	10:38	NG 86009 54831	186010	854831			Ob Gorm Beag, E end of middle mussel line.
3	26/08/2013	10:38	NG 86046 54778	186047	854779			Ob Gorm Beag, SE corner of mussel lines (3rd and final line).
4	26/08/2013	10:40	NG 85991 54627	185991	854627			Ob Gorm Beag, SW corner of mussel lines (W end of final line)
5	26/08/2013	10:40	NG 85937 54700	185938	854700			Ob Gorm Beag, W end of middle line.
6	26/08/2013	10:41	NG 85867 54828	185867	854829			Ob Gorm Beag, NW corner of mussel lines.
7	26/08/2013	10:45	NG 85883 54879	185884	854880		LTSW1	Ob Gorm Beag, outer line seawater sample
8	26/08/2013	10:45	NG 85883 54879	185884	854880	Fig 3	LTSF1	Ob Gorm Beag, outer line mussel sample.
9	27/08/2013	10:56	NG 85900 54906	185901	854907		CTD	Ob Gorm Beag, CTD outer cast.
10	27/08/2013	11:02	NG 86008 54669	186009	854669		LTSF2	Ob Gorm Beag, mussel sample from middle of south line - old mussels with young spat, and heavily fouled with other organisms.
11	26/08/2013	11:03	NG 86011 54670	186011	854670		CTD	Ob Gorm Beag, CTD inner cast (south line).
12	26/08/2013	11:24	NG 86797 54993	186798	854993			Ob Gorm Mor, NE corner of (3) mussel lines.
13	26/08/2013	11:25	NG 86830 54934	186831	854935			Ob Gorm Mor, E end of middle line.
14	26/08/2013	11:25	NG 86868 54859	186869	854859			Ob Gorm Mor, SE corner of lines (E end of 3rd and final line).
15	26/08/2013	11:26	NG 86787 54767	186788	854768			Ob Gorm Mor, SW corner of mussel lines.
16	26/08/2013	11:27	NG 86719 54815	186719	854815			Ob Gorm Mor, W end of middle mussel line.
17	26/08/2013	11:28	NG 86677 54874	186678	854874			Ob Gorm Mor, NW corner of mussel lines.
18	26/08/2013	11:29	NG 86705 54933	186705	854934		LTSW3	Ob Gorm Mor, seawater sample outer line.
19	26/08/2013	11:29	NG 86704 54934	186705	854935		CTD	Ob Gorm Mor, CTD outer cast.
20	26/08/2013	11:33	NG 86705 54936	186705	854936		LTSF3	Ob Gorm Mor, outer mussel sample - old mussels with young spat present, heavily fouled with other organisms.
21	26/08/2013	11:40	NG 86818 54820	186818	854821		LTSW4	Ob Gorm Mor, seawater sample inner line middle (3rd line).
22	26/08/2013	11:41	NG 86821 54818	186821	854818		CTD	Ob Gorm Mor, CTD cast at inner line, middle.
23	26/08/2013	11:45	NG 86822 54820	186822	854820		LTSF4	Ob Gorm Mor, mussel sample inner line middle; mussel lines look like they have not been tended for some time. Very heavily fouled with barnacles, good spat settlement.
24	26/08/2013	12:14	NG 87481 55250	187481	855251			Dubh Aird, NE corner of mussel lines.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
25	26/08/2013	12:15	NG 87518 55179	187518	855180			Dubh Aird, SE corner of mussel lines.
26	26/08/2013	12:16	NG 87418 55113	187419	855114			Dubh Aird, SW corner of mussel lines.
27	26/08/2013	12:17	NG 87377 55123	187378	855124			Dubh Aird, W end of middle mussel line.
28	26/08/2013	12:18	NG 87422 55196	187422	855196			Dubh Aird, NW corner of mussel lines.
29	26/08/2013	12:18	NG 87420 55154	187420	855155	Fig 4	LTSW5	Dubh Aird, seawater sample (Rubha na Feola site).
30	26/08/2013	12:20	NG 87420 55149	187420	855149		CTD	Dubh Aird, middle mussel line CTD cast.
31	26/08/2013	12:25	NG 87425 55148	187425	855149		LTSF5	Dubh Aird, middle mussel line shellfish sample. Dubh-Aird lines cleaner than the other two sites with a very good mussel spat settlement. Centre line of the three is out of shape and clumped and shifted to the N.
32	26/08/2013	14:35	NG 84230 57362	184230	857362		LTFW1	Inveralligin stream FW sample. Sample associated with observations in waypoint 33.
33	26/08/2013	14:37	NG 84227 57360	184228	857361			Inveralligin stream measurements: Width 5.2 m, Measurement 1: 35 cm depth, flow 0.273 m/s, SD 0.011; Measurement 2: 32 cm depth, flow 0.174 m/s, SD 0.035; Measurement 3 20 cm depth, flow 0.153 m/s, SD 0.014. River bed composed of large boulders making accurate measurement difficult.
34	26/08/2013	15:03	NG 87070 57159	187070	857160		LTFW2	Torridon House stream Abhainn Coire Mhic Nobuil, Freshwater sample. Sample associated with observations in waypoint 35.
35	26/08/2013	15:10	NG 87071 57166	187071	857167			Torridon House stream Abhainn Coire Mhic Nobuil measurements: Width 5.1m. Measurement 1: 20 cm depth, flow 0.123 m/s, SD 0.025; Measurement 2: 55 cm depth, flow 0.533 m/s, SD 0.022. Stream bed of large boulders making representative measurement difficult.
36	26/08/2013	15:44	NG 89411 56523	189411	856523	Fig 5	LTSW6	Torridon village seawater sample.
37	26/08/2013	16:04	NG 90260 55016	190261	855017		LTFW3	Torridon river freshwater sample (taken at roadbridge due to easier access to river). Associated with observations made in Waypoint 38.
38	26/08/2013	16:06	NG 90258 55017	190259	855018			Torridon river measurements: Width 4.7 m. Measurement 1: 40 cm depth, flow 0.657 m/s, SD 0.051; Measurement 2: 57 cm depth, flow 0.148 m/s, SD 0.007. River bed of large boulders.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
39	26/08/2013	16:37	NG 88802 54333	188803	854334		LTFW4	Torridon Hotel stream Allt Coire Roill freshwater sample. Associated with observations made in waypoint 40.
40	26/08/2013	16:39	NG 88808 54330	188808	854330	Fig 6		Torridon Hotel stream Allt Coire Roill measurements: Width approx. 4 m. Measurement 1; 21 cm depth, flow 0.131 m/s, SD 0.021. Measurement 2; 21 cm depth, flow 0.427 m/s, SD 0.026. Stream bed again very rocky, making accurate flow measurement very difficult. Stream examined for ~250m from bridge location, no sign of any discharge pipe. Access to banks of river difficult due to rocks and as the property is in private ownership, although two photos taken of manholes present in hotel grounds on path to river.
41	26/08/2013	16:54	NG 88851 54279	188851	854280			Possible location of septic tank - 3x metal manhole covers below hotel in field. Didn't take photo at site as immediately on hotel grounds (private property). End of survey, day 1.
42	27/08/2013	9:22	NG 86180 54252	186181	854253	Fig 7		Ob Gorm Beag photograph overview - taken from track above bay on way to start of survey day 2.
43	27/08/2013	9:37	NG 87184 54979	187184	854980	Fig 8		Start of survey Dubh -Aird. Shore access impossible due to thick rhododendron. Dubh Aird mussel farm photographed.
44	27/08/2013	9:42	NG 87142 55106	187142	855106			Dubh Aird mussel harvest platform on lower beach. No other gear on the shoreline. Dubh-Aird peninsula is heavily overgrown on the N and W sides with rhododendron. This vegetation combined with a sheer or steep-faced shoreline made traverse impractical and unsafe. Overview of the shore at various points was obtained to confirm that no activity or discharge was present.
45	27/08/2013	9:53	NG 87215 55135	187215	855135	Fig 9		Abandoned campsite with remains of tent in two fire hearths.
46	27/08/2013	9:58	NG 86994 55052	186995	855052	Fig 10		W shoreline of Dubh-Aird peninsula. Ob Gorm Mor mussel lines photographed. Dub-Aird shoreline S along the W side impractical to follow. Returned to track to move west. No activity or discharges seen on noted shoreline when viewed from a distance.
47	27/08/2013	10:12	NG 87037 54772	187037	854773			Dubh-Aird peninsula, W shoreline photographed.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
48	27/08/2013	10:22	NG 86643 54540	186643	854541		LTFW5	Freshwater sample, at un-named stream at SW edge of Ob Gorm Mor. Sample associated with observations made in waypoint 49.
49	27/08/2013	10:22	NG 86646 54537	186646	854538			Un-named burn: Width around 30cm. Insufficient flow to use flowmeter. Bucket estimation of flow: 0.5ltr/second.
50	27/08/2013	10:33	NG 86522 54895	186522	854895	Fig 11		Photograph of W side Dubh -Aird peninsula and house on Mas an Aird Mhoir
51	27/08/2013	10:46	NG 86364 55139	186365	855139	Fig 12		Aird Mhoir peninsula: Septic tanks cover at lone house on the peninsula. Tank appears to soakaway into marshy ground - no discharge pipe observed.
52	27/08/2013	10:58	NG 86024 54984	186024	854985	Fig 13		Ob Gorm Beag photograph overview. Immediate shoreline W side of Aird Mhoir peninsula not accessible (photographed).
53	27/08/2013	11:16	NG 86199 54335	186199	854336		LTFW6	Ob Gorm Beag, head of loch, freshwater sample from small, un-named burn as it runs under track. Sample associated with observations made in waypoint 54.
54	27/08/2013	11:20	NG 86195 54341	186195	854341			Ob Gorm Beag, head of loch, small, un-named burn: Width <0.5 m. Bucket estimation of flow: approx. 0.5ltr/second
55	27/08/2013	11:25	NG 85996 54444	185997	854444	Fig 14		Photograph taken showing density of *Rhodedendrum ponticum* brush - access to the immediate shoreline impossible due to the dense growth.
56	27/08/2013	11:32	NG 85750 54535	185751	854535			Ob Gorm Beag W side freshwater stream: Stream crossing at track where it appears to be a cut drain channel.
57	27/08/2013	11:39	NG 85873 54658	185873	854659		LTFW7	Freshwater sample taken about 20 m from shore. Sample associated with observations made in waypoint 58.
58	27/08/2013	11:42	NG 85872 54661	185872	854661			Stream measurements; Width 45 cm, depth 6 cm, flow 0.101 m/s, SD 0.007.
59	27/08/2013	11:51	NG 85769 54784	185769	854784			Bay W of Ob Gorm Beag - no discharge or activity.
60	27/08/2013	12:07	NG 85279 54723	185280	854724	Fig 15		Corran Badan Mhugaidh (bay). Beach of Torridonian sandstone. No rubbish or shoreline flotsam.
61	27/08/2013	12:18	NG 84791 54630	184792	854631			River Balgy mouth. View upstream taken and across to W side.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
62	27/08/2013	12:24	NG 84697 54452	184698	854453	Fig 16		Tanks, recessed into bank, appearing disused. One round tank and the second (downstream) tank rectangular with a wooden walkway surround. A 6 cm diameter pipe appears to be a feedpipe from upstream.
63	27/08/2013	12:33	NG 84694 54289	184695	854290		LTFW8	River Balgy freshwater sample from upstream of the road bridge. Sample associated with waypoint 64.
64	27/08/2013	12:35	NG 84695 54290	184695	854290			River Balgy measurements (river split into two sections, so measured separately): 1st section width 11 m. Measurement 1: 29 cm depth, 0.703 m/s SD 0.038; Measurement 2: 30 cm depth 0.848 m/s SD 0.025; Measurement 3: 35 cm depth 0.517 m/s SD 0.037; Measurement 4: 20 cm depth, 0.376 m/s SD 0.019; 2nd Section - width 5.5 m; Measurement 1: 19 cm depth 0.443 m/s SD 0.020; Measurement 2: 15 cm depth 0.338 m/s SD 0.011
65	27/08/2013	13:04	NG 84644 54379	184645	854380	Fig 17		River Balgy W bank - concrete box approx. 1m in diameter with small pipes entering and leaving. No sign of entrance/exit with river.
66	27/08/2013	13:12	NG 84632 54778	184632	854778			River Balgy mouth W bank, small abandoned stone jetty. Disused appearance, no sign of recent activity.
67	27/08/2013	13:38	NG 83716 54705	183716	854706	Fig 18	LFSW7	LTSW7 - sample taken at site of Marine Harvest Salmon farm shore base. No activity ashore & slipway & pontoon system at shore. Four moorings in bay with no boats present.
68	26/08/2013	11:03	NG 86011 54670	183716	854706		LTSW2	Ob Gorm Beag planned seawater sample. End of survey.

Photographs referenced in the table can be found attached as Figures 3 – 18.

Sampling

Boat sampling on the mussel lines took place on the 26th August (via Kenny and Gemma Livingstone, www.torridonseatours.com) but due to a bank holiday, all post offices were closed so the samples could not be sent that day. With prior agreement from Cefas, the mussels and the freshwater & seawater samples taken on the 26th were kept in a cool-box after collection until they could be sent on the following day. Two boxes (Biotherm 30 & 10) were dispatched to GSS on the afternoon of the 27th. Sample temperature on arrival at GSS was between 5.8°C and 7.9°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 formula:

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

Table 2. Water Sample Results

No.	Date	Sample	Grid Ref	Type	21. *E. coli* (cfu/100ml)	Salinity (ppt)
1	26/08/2013	LTSW1	NG 85883 54879	Seawater	0	35.77
2	26/08/2013	LTSW2	NG 86011 54670	Seawater	3	35.95
3	26/08/2013	LTSW3	NG 86705 54933	Seawater	0	35.95
4	26/08/2013	LTSW4	NG 86818 54820	Seawater	0	35.59
5	26/08/2013	LTSW5	NG 87420 55154	Seawater	0	35.05
6	26/08/2013	LTFW1	NG 84230 57362	Freshwater	10	
7	26/08/2013	LTFW2	NG 87070 57159	Freshwater	<10	
8	26/08/2013	LTSW6	NG 89411 56523	Seawater	3	28.18
9	26/08/2013	LTFW3	NG 90260 55016	Freshwater	<10	
10	26/08/2013	LTFW4	NG 88802 54333	Freshwater	<10	
11	27/08/2013	LTFW5	NG 86643 54540	Freshwater	10	
12	27/08/2013	LTFW6	NG 86199 54335	Freshwater	<10	
13	27/08/2013	LTFW7	NG 85873 54658	Freshwater	10	
14	27/08/2013	LTFW8	NG 84694 54289	Freshwater	<10	
15	27/08/2013	LFSW7	NG 83716 54705	Seawater	0	35.23

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	22. *E. coli* (MPN/100g)
1	26/08/2013	LTSF1	NG 85883 54879	Mussels	<20
2	26/08/2013	LTSF2	NG 86008 54669	Mussels	<20
3	26/08/2013	LTSF3	NG 86705 54936	Mussels	<20
4	26/08/2013	LTSF4	NG 86822 54820	Mussels	20
5	26/08/2013	LTSF5	NG 87425 55148	Mussels	170

Photographs

Figure 3: Ob Gorm Beag mussel sample (LTSF1) from middle of N (outermost) line. Waypoint 8.

Figure 4: Dubh Aird, SE corner of mussel lines at LTSW5 sample site showing plastic floats. Waypoint 29.

Figure 5: Western end of the village of Torridon, with public jetty visible on the middle left. Waypoint 36. Site of seawater sample LTSW6.

Figure 6: Allt Coire Roill river, looking upstream with Torridon Hotel behind. Waypoint 40.

Figure 7: Ob Gorm Beag overview from South (photo taken while walking to the start of survey, day 2). Waypoint 42.

Figure 8: Dubh Aird site, viewed from the West on the 2nd day of survey. The W end of Torridon village is in the background on the far shore. Waypoint 43.

Figure 9: Abandoned campsite and fire hearth on shore to the West of Dubh Aird site. Waypoint 45.

Figure 10: Ob Gorm Mor site, taken on day 2 of the survey, looking west. Waypoint 46.

Figure 11: Sole house on Aird Mhor peninsula with typical shoreline below. Waypoint 50.

Figure 12: Septic tank for house on Aird Mhor peninsula with longitudinal crack through concrete. Waypoint 51.

Figure 13: Overview of Ob Gorm Beag from the Aird Mhor peninsula, showing the difficult shoreline and access along the loch, with mussel lines present. Waypoint 52.

Figure 14: Typical *Rhodedendrum ponticum* foliage in the area between the track and shoreline, limiting access. Waypoint 55.

Figure 15: Shoreline in Corran Badan Mhugaidh, looking west. Waypoint 60.

Figure 16: Two tanks recessed into riverbank next to River Balgy. Waypoint 62.

Figure 17: Concrete box with pipe entering, noted on west bank of River Balgy. Waypoint 65

Figure 18: Inner Loch Torridon Marine Harvest shore base, with pontoon and moorings visible. Waypoint 67.

6. SEPA Discharge Consents

Licence No.	NGR	Site Name	Discharge Type	Discharges to	PE
CAR/L/1002062	NG 89250 56500	Torridon (Fasaig)	Sewage (Public) Primary	Loch Torridon	-
CAR/L/1003969	NG 81500 53500	Shieldaig Village Drainage	Sewage (Public) Primary	Loch Shieldaig	-
CAR/R/1079009	NG 83249 57547	Dwelling	Sewage (Private) Tertiary	U/N W/C	6
CAR/R/1031218	NG 83284 57539	Dwelling	Sewage (Private) Secondary	U/N W/C	6
CAR/R/1032958	NG 89836 55498	Dwelling	Sewage (Private) Secondary	Upper Loch Torridon	15
CAR/R/1079045	NG 78066 56058	Dwelling	Sewage (Private) Secondary	Soakaway	5
CAR/R/1015695	NG 81604 52329	Dwelling	Sewage (Private) Primary	Land	5
CAR/R/1018379	NG 80220 60660	Dwelling	Sewage (Private) Primary	Land	10
CAR/R/1027003	NG 78254 55978	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1031509	NG 81230 52817	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1032952	NG 89930 55560	2 Dwellings	Sewage (Private) Primary	Soakaway	15
CAR/R/1032969	NG 90490 55749	Countryside Centre, Torridon, Achnasheen	Sewage (Private) Primary	Soakaway	15
CAR/R/1042787	NG 83320 58200	Dwelling	Sewage (Private) Primary	Soakaway	10
CAR/R/1046635	NG 89576 54595	2 Dwellings	Sewage (Private) Primary	Upper Loch Torridon	10
CAR/R/1047058	NG 83340 57578	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1047384	NG 83236 57658	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1048789	NG 82661 57703	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1048860	NG 84803 57594	Dwelling	Sewage (Private) Primary	U/T of Upper Loch Torridon	5
CAR/R/1048861	NG 84700 57530	Dwelling	Sewage (Private) Primary	Upper Loch Torridon	5
CAR/R/1049841	NG 83217 58163	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1049858	NG 84290 57540	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1049869	NG 84560 57760	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1050499	NG 84899 57656	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1051546	NG 84610 57621	Dwelling	Sewage (Private) Primary	Allt na Criche	5
CAR/R/1052188	NG 84950 57700	Dwelling	Sewage (Private) Primary	Soakaway	6
CAR/R/1052338	NG 85430 57550	Dwelling	Sewage (Private) Primary	Soakaway	5

Licence No.	NGR	Site Name	Discharge Type	Discharges to	PE
CAR/R/1052488	NG 85040 57692	Dwelling	Sewage (Private) Primary	U/N W/C	5
CAR/R/1052519	NG 84691 57566	Dwelling	Sewage (Private) Primary	Loch Torridon	6
CAR/R/1052524	NG 84400 57740	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1052792	NG 84190 57280	Dwelling	Sewage (Private) Primary	Soakaway	6
CAR/R/1052989	NG 85222 57599	Dwelling	Sewage (Private) Primary	Soakaway	7
CAR/R/1053286	NG 84266 57310	Dwelling	Sewage (Private) Primary	Soakaway	6
CAR/R/1053383	NG 83190 57998	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1053567	NG 85212 57529	Dwelling	Sewage (Private) Primary	Loch Torridon	7
CAR/R/1055576	NG 79610 60280	Dwelling	Sewage (Private) Primary	Land	5
CAR/R/1055577	NG 79850 59790	Dwelling	Sewage (Private) Primary	Land	5
CAR/R/1055802	NG 79596 60377	Dwelling	Sewage (Private) Primary	Allt a Chlada	5
CAR/R/1055902	NG 79430 60300	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1067434	NG 84164 57273	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1071289	NG 80590 53339	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1071348	NG 78310 56770	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1072794	NG 85716 57393	Dwelling	Sewage (Private) Primary	Allt Mhurchaidh	5
CAR/R/1074683	NG 78350 56010	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1076184	NG 78360 56680	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1076980	NG 78163 56785	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1077574	NG 84536 57376	Dwelling	Sewage (Private) Primary	Upper Loch Torridon	5
CAR/R/1077598	NG 86233 57241	Dwelling	Sewage (Private) Primary	U/N W/C	5
CAR/R/1077740	NG 81090 60080	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1077969	NG 90425 55032	Dwelling	Sewage (Private) Primary	Rivver Torridon	6
CAR/R/1077985	NG 90139 55863	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1078031	NG 84703 57636	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1078070	NG 84476 57648	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1078952	NG 84201 57507	Dwelling	Sewage (Private) Primary	Soakaway	6
CAR/R/1078955	NG 84405 57642	Dwelling	Sewage (Private) Primary	Soakaway	8
CAR/R/1079029	NG 78066 56190	Dwelling	Sewage (Private) Primary	Loch Beag	5

Licence No.	NGR	Site Name	Discharge Type	Discharges to	PE
CAR/R/1079448	NG 80650 53420	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1079798	NG 85740 54210	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1080054	NG 89580 56571	Dwelling	Sewage (Private) Primary	U/N W/C	5
CAR/R/1081671	NG 84340 57470	Dwelling	Sewage (Private) Primary	Soakaway	6
CAR/R/1082298	NG 79880 60510	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1083935	NG 90200 54980	Dwelling	Sewage (Private) Primary	Soakaway	6
CAR/R/1089419	NG 79247 54498	Dwelling	Sewage (Private) Primary	Soakaway	5
CAR/R/1095576	NG 83415 57359	Dwelling	Sewage (Private) Primary	Coastal Waters	5
CAR/R/1096952	NG 79820 59720	Dwelling	Sewage (Private) Primary	Loch Diabaig	10
CAR/R/1100243	NG 80479 53283	Dwelling	Sewage (Private) Primary	Loch Shieldaig	
CAR/R/1101107	NG 82568 57634	Dwelling	Sewage (Private) Primary	Land	5
CAR/R/1104564	NG 82980 57890	Dwelling	Sewage (Private) Primary	Soakaway	6
CAR/L/1008761	NG 8002 6058	Diabeg Water Treatment Works, Diabeg	Other Effluent Potable Water Treatment and Supply		-
CAR/S/1009981	NG 83303 58124	Alligin Water Treatment Works, Near Alligin	Other Effluent Potable Water Treatment and Supply		-
CAR/L/1002917	NG 78850 56250	Ardheslaig MCFF, Loch Shieldaig	Fish Farm Marine Cage		-
CAR/L/1010002	NG 82400 55900	Camus an Leim MCFF, Loch Torridon, Shieldaig	Fish Farm Marine Cage		-
CAR/L/1003924	NG 86062 52093	Torridon Smolts Ltd, Loch Damh (North) FCFF	Fish Farm Freshwater Cage	Loch Damh	-

Appendix 7. Inner Loch Torridon CTD data

Data obtained during the shoreline survey. The locations of the casts are shown in Figure A7.1.

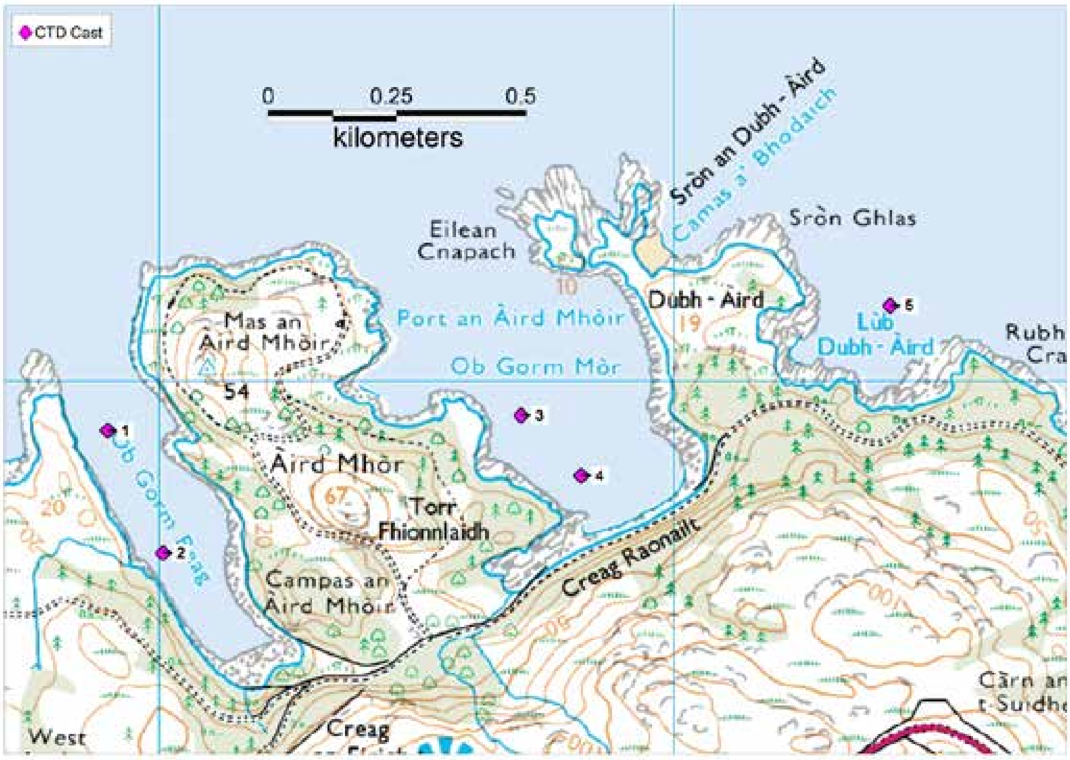

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Figure A7.1 Location of CTD cast

CAST 1

Data Header

% Device	10G100653
% File name	10G100653_20130826_095653
% Cast time (local)	26/08/2013 10:56
% Sample type	Cast
% Cast data	Processed
% Location source	GPS
% Start latitude	57.5334605
% Start longitude	-5.5782431
% Start GPS horizontal error(Meter)	1.830000043
% Start GPS vertical error(Meter)	3.25999999
% Start GPS number of satellites	6
% Cast duration (Seconds)	89.4
% 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)
0.148977111	12.51797231	33.92799746
0.446915517	12.51595227	33.93082714
0.74486006	12.51404791	33.91448889
1.04280526	12.51980264	33.9229954
1.340749266	12.51248486	33.92173143
1.638692739	12.51191493	33.92277653
1.936636081	12.51352218	33.92019002
2.234579287	12.50901243	33.92028101
2.5325215	12.50386218	33.92362519
2.830463238	12.5112871	33.92208805
3.12840509	12.50748129	33.92055961
3.426346322	12.50223982	33.92235761
3.724286575	12.49775628	33.92384571
4.022226172	12.49698806	33.9239024
4.320164727	12.48496867	33.92691307
4.618101563	12.46949192	33.92931783
4.91603733	12.45638118	33.92627965
5.213972976	12.45482208	33.92375719
5.511908043	12.46203116	33.92986115
5.809842349	12.45313976	33.9271256
6.107776057	12.44752263	33.9285714
6.405711932	12.4357495	33.90057882
6.703647076	12.41547079	33.92407938
7.001577771	12.40377254	33.92911909
7.299507283	12.40054495	33.92790033
7.597436006	12.40183978	33.93266912
7.895363511	12.39693617	33.9348389
8.193290577	12.3944455	33.93175778
8.491216727	12.38425465	33.93684651
8.789140306	12.37232208	33.94609345
9.087061559	12.36885417	33.95068582
9.384982445	12.37172432	33.94623524
9.682903884	12.37565597	33.944505
9.980824793	12.36690288	33.94677294
10.27874513	12.36160319	33.94307538
10.57666583	12.36748758	33.94075075
10.87458616	12.36479713	33.94424889
11.17250472	12.35844029	33.95115707
11.47042251	12.3586927	33.94666402
11.76834016	12.36124964	33.950066
12.12597921	12.35538102	33.95035506

CAST 2

Data Header

% Device	10G100653
% File name	10G100653_20130826_100222
% Cast time (local)	26/08/2013 11:02
% Sample type	Cast
% Cast data	Processed
% Location source	GPS
% Start latitude	57.5313809
% Start longitude	-5.5762342
% Start GPS horizontal error(Meter)	1.899999976
% Start GPS vertical error(Meter)	3.099999905
% Start GPS number of satellites	6
% Cast duration (Seconds)	1726.6
% Samples per second	5
Calibration Date	March 2013
Calibration offset for Temperature	-0.033
Calibration offset for Salinity	0.029

CTD data (calibration offsets applied)

Depth (Meter)	Temperature (Celsius)	Salinity (Practical Salinity Scale)
0.148979865	12.50653382	33.90235455
0.446922027	12.4976718	33.91033498
0.744868547	12.49151982	33.90475774
1.042815003	12.49095594	33.9062647
1.340760726	12.48614839	33.90694312
1.638705429	12.47521808	33.90841283
1.936649619	12.47993352	33.9069817
2.234594222	12.47306795	33.9012273
2.532537814	12.45745807	33.90737882
2.830480411	12.45197983	33.90180939
3.12842197	12.44466696	33.91043029
3.426361502	12.43924324	33.91366041
3.724300698	12.43671548	33.90845116
4.022239652	12.43657093	33.91216725
4.320177785	12.43751533	33.91297763
4.618115237	12.43797315	33.91559101
4.916052232	12.43811408	33.91421921
5.213988901	12.43674329	33.91520675
5.51192492	12.43681707	33.91670087
5.809860824	12.43885202	33.91378438
6.107796261	12.4369852	33.91791776
6.40573067	12.43290453	33.9184554
6.703664202	12.42221679	33.91905066
7.001596875	12.41258111	33.9180314
7.299528006	12.40304715	33.92499186
7.597457141	12.39757651	33.92904044

7.895385805	12.39667733	33.9246185
8.193313633	12.39808949	33.93361101
8.49124061	12.39876562	33.92973291
8.78916781	12.40240542	33.92974132
9.087094635	12.4002328	33.9304589
9.450843639	12.39872975	33.93127444

CAST 3

Data Header

% Device	10G100653
% File name	10G100653_20130826_103139
% Cast time (local)	26/08/2013 11:31
% Sample type	Cast
% Cast data	Processed
% Location source	GPS
% Start latitude	57.534105
% Start longitude	-5.5648898
% Start GPS horizontal error(Meter)	1.899999976
% Start GPS vertical error(Meter)	3.099999905
% Start GPS number of satellites	6
% Cast duration (Seconds)	82.6
% Samples per second	5
Calibration Date	March 2013
Calibration offset for Temperature	-0.033
Calibration offset for Salinity	0.029

CTD data (calibration offsets applied)

Depth (Meter)	Temperature (Celsius)	Salinity (Practical Salinity Scale)
0.148998212	12.72566333	33.7934489
0.44697783	12.69520493	33.79448034
0.744960455	12.68204148	33.79882421
1.042941948	12.68046292	33.79783345
1.340922598	12.6749919	33.80156725
1.638901942	12.66943768	33.80367743
1.936880635	12.6661843	33.80216084
2.234858836	12.66238134	33.80329404
2.532836531	12.64541124	33.79844245
2.830812476	12.62768945	33.80711564
3.128785666	12.61387452	33.81198601
3.426756935	12.60469811	33.81541967
3.724726266	12.59702037	33.82198313
4.022695058	12.59149432	33.81392014
4.320663207	12.56357145	33.81630717
4.618627852	12.54140155	33.82948373
4.916589557	12.53439428	33.83211209
5.214550445	12.52784418	33.83036992
5.512510733	12.51751186	33.83024099
5.810468701	12.48296753	33.83674965

6.108424763	12.4622706	33.8303723
6.406379283	12.42861925	33.83388325
6.704329959	12.40497882	33.84722516
7.00227684	12.39350276	33.85584797
7.300221571	12.38621029	33.85867373
7.598164319	12.37810349	33.86663709
7.896104798	12.363542	33.87020613
8.194043494	12.34622249	33.87155524
8.491980665	12.33164726	33.87285289
8.789916514	12.32374705	33.87473225
9.087850401	12.31308203	33.88268751
9.385780997	12.30361859	33.89597872
9.683709103	12.29342137	33.89694334
9.981635953	12.28252601	33.89892245
10.27956127	12.26881477	33.90152674
10.57748461	12.25644483	33.90698916
10.87540577	12.24985299	33.91316517
11.17332523	12.24426257	33.91619925
11.47124336	12.23993281	33.91949629
11.76916096	12.23921578	33.91666635
12.06707864	12.23958914	33.91570059
12.36499572	12.23279278	33.91751252
12.66291206	12.23556376	33.91828148
12.96082776	12.23016633	33.91947877
13.26544268	12.23061756	33.91997104

CAST 4

Data Header

% Device	10G100653
% File name	10G100653_20130826_104310
% Cast time (local)	26/08/2013 11:43
% Sample type	Cast
% Cast data	Processed
% Location source	GPS
% Start latitude	57.5331145
% Start longitude	-5.5628373
% Start GPS horizontal error(Meter)	2.529999971
% Start GPS vertical error(Meter)	2.799999952
% Start GPS number of satellites	6
% Cast duration (Seconds)	84.4
% 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)
0.148998212	12.72566333	33.7934489
0.44697783	12.69520493	33.79448034
0.744960455	12.68204148	33.79882421
1.042941948	12.68046292	33.79783345
1.340922598	12.6749919	33.80156725
1.638901942	12.66943768	33.80367743
1.936880635	12.6661843	33.80216084
2.234858836	12.66238134	33.80329404
2.532836531	12.64541124	33.79844245
2.830812476	12.62768945	33.80711564
3.128785666	12.61387452	33.81198601
3.426756935	12.60469811	33.81541967
3.724726266	12.59702037	33.82198313
4.022695058	12.59149432	33.81392014
4.320663207	12.56357145	33.81630717
4.618627852	12.54140155	33.82948373
4.916589557	12.53439428	33.83211209
5.214550445	12.52784418	33.83036992
5.512510733	12.51751186	33.83024099
5.810468701	12.48296753	33.83674965
6.108424763	12.4622706	33.8303723
6.406379283	12.42861925	33.83388325
6.704329959	12.40497882	33.84722516
7.00227684	12.39350276	33.85584797
7.300221571	12.38621029	33.85867373
7.598164319	12.37810349	33.86663709
7.896104798	12.363542	33.87020613
8.194043494	12.34622249	33.87155524
8.491980665	12.33164726	33.87285289
8.789916514	12.32374705	33.87473225
9.087850401	12.31308203	33.88268751
9.385780997	12.30361859	33.89597872
9.683709103	12.29342137	33.89694334
9.981635953	12.28252601	33.89892245
10.27956127	12.26881477	33.90152674
10.57748461	12.25644483	33.90698916
10.87540577	12.24985299	33.91316517
11.17332523	12.24426257	33.91619925
11.47124336	12.23993281	33.91949629
11.76916096	12.23921578	33.91666635
12.06707864	12.23958914	33.91570059
12.36499572	12.23279278	33.91751252
12.66291206	12.23556376	33.91828148
12.96082776	12.23016633	33.91947877
13.26544268	12.23061756	33.91997104

CAST 5

Data Header

% Device	10G100653
% File name	10G100653_20130826_112102
% Cast time (local)	26/08/2013 12:21
% Sample type	Cast
% Cast data	Processed
% Location source	GPS
% Start latitude	57.5363515
% Start longitude	-5.5531174
% Start GPS horizontal error(Meter)	2.75
% Start GPS vertical error(Meter)	3.190000057
% Start GPS number of satellites	6
% Cast duration (Seconds)	74
% 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)
0.149072889	13.73148522	33.39302067
0.447196144	13.67995727	33.42201262
0.745315318	13.58678639	33.43990021
1.043409924	13.31788322	33.54246398
1.341468564	13.04941442	33.6167874
1.639500735	12.89599253	33.6659882
1.937518411	12.84035551	33.68913213
2.235530307	12.80488697	33.69116189
2.53353527	12.74612912	33.72382312
2.83153245	12.71363875	33.73419386
3.129524715	12.68171923	33.74820983
3.427513271	12.65580775	33.74955135
3.72549821	12.61029821	33.75936132
4.023477219	12.54707646	33.77187542
4.32145101	12.46937924	33.7673846
4.619417344	12.40736625	33.8001781
4.917374876	12.3677716	33.81722193
5.215328778	12.34587484	33.81412741
5.513280426	12.33612906	33.82639283
5.811229082	12.32374461	33.83222357
6.109175351	12.30317601	33.83643426
6.407119259	12.30166077	33.84472427
6.70506185	12.28722409	33.84120124
7.003002258	12.27049014	33.85340507
7.300939417	12.26895958	33.86254809
7.598874556	12.27020973	33.86828772
7.896810938	12.27162085	33.84921098

8.194745789	12.26879879	33.87854743
8.49267678	12.26574645	33.87905103
8.790606945	12.25909503	33.88050299
9.088535853	12.25479653	33.88452538
9.386463242	12.25510341	33.89002629
9.684390408	12.24477307	33.88105508
9.98231696	12.24091594	33.88899727
10.28024223	12.24769155	33.8901984
10.57816736	12.24521138	33.88830587
10.87609232	12.24220141	33.88735163
11.17401677	12.23606568	33.88765616
11.47194041	12.23216057	33.88906706
11.76986325	12.23406039	33.89129953
12.06778588	12.22440263	33.88603151
12.30756641	12.22434638	33.89329172