Scottish Sanitary Survey Report

Sanitary Survey Report
Kyle of Tongue
HS-103
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Approvals

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Partner Organisations

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

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Appendices

I. Executive Summary

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

The purpose of the sanitary survey is to demonstrate compliance with the requirements stated in Annex II (Chapter II Paragraph 6) of Regulation (EC) 854/2004. The sanitary survey results in recommendations on the location of RMPs, the frequency of sampling for microbiological monitoring, and the boundaries of the production areas deemed to be represented by the RMPs.

A sanitary survey was undertaken on the classified mussel fishery at Kyle of Tongue 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 following is a summary of the main findings of the sanitary survey.

The Kyle of Tongue is an area of shallow tidal sandbanks on the northern coast of Scotland, east of Cape Wrath. The Kyle of Tongue hosts a Pacific oyster aquaculture farm extending over an area of approximately 1.5 km on intertidal sands along the east shore, north of the causeway.

Overall, the fishery is is subject to low levels of faecal contamination. The main sources of contamination to the fishery are:

- Sewage discharged from a private septic tank to shore approximately 200 m southeast of the oyster farm
- Diffuse contamination from sheep kept on pastures to the south and northeast of the oyster farm
- Sewage discharges from community septic tanks at Coldbackie and Tongue

Faecal contamination from diffuse sources is most likely to be carried in watercourses and other surface runoff to the sea around the fishery. Transport of contaminants within the Kyle and Tongue Bay is likely to be complex, but there will be a general seaward trend in surface flows.

Significant seasonal variation was seen in results, with higher results occurring in summer and autumn. This broadly corresponds with predicted increases in human, livestock and seabird populations in the area.

Summary of recommendations

It is recommended that the current production area boundary be curtailed somewhat to exclude sources around the northwest shoreline and the east shoreline around Coldbackie. The southern boundary should be extended slightly to ensure that the entire oyster farm is included within the boundary.

The RMP should be relocated to NC 5913 5900, on the southeast corner of the oyster farm where it would better reflect potential contamination arising southeast of the fishery.

II. Sampling Plan

Production Area	Kyle of Tongue
Site Name	Kyle of Tongue oysters
SIN	HS-103-303-13
Species	Pacific oysters
Type of Fishery	Trestle aquaculture
NGR of RMP	NC 5913 5900
East	259130
North	959000
Tolerance (m)	10
Depth (m)	not applicable
Method of Sampling	Hand
Frequency of Sampling	Monthly
Local Authority	Highland Council - Sutherland
Authorised Sampler(s)	Anne Grant
Local Authority Liaison Officer	Alan Yates
Production Area Boundaries	The area bounded by lines drawn between NC 5731 5909 and NC 5913 5888 and between NC 5879 6058 and NC 6021 6011 and extending to MHWS

III. Report

1. General Description

The Kyle of Tongue is an area of shallow tidal sandbanks on the northern coast of Scotland, east of Cape Wrath, in the Sutherland area of the Highland Council. The Kyle's mouth is at Tongue Bay which has a northerly aspect and opens to the North Atlantic. The general location of the study area is shown in Figure 1.1.

The Kyle is about 11 km in length with a maximum width of 1.7 km although it narrows considerably towards the head. The A838 crosses where there is a natural causeway across most of the Kyle, approximately half way down.

The surrounding area is sparsely inhabited, with crofting townships clustered in three main areas: around the northwest shore (Talmine, Skinnet, and Midtown), along the southeast shore near the mouth of the Rhian Burn (Tongue) and further north along the east shore at the mouth of the Strathtongue Burn (Coldbackie, Blandy and Skullomie).

This survey is being undertaken 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.

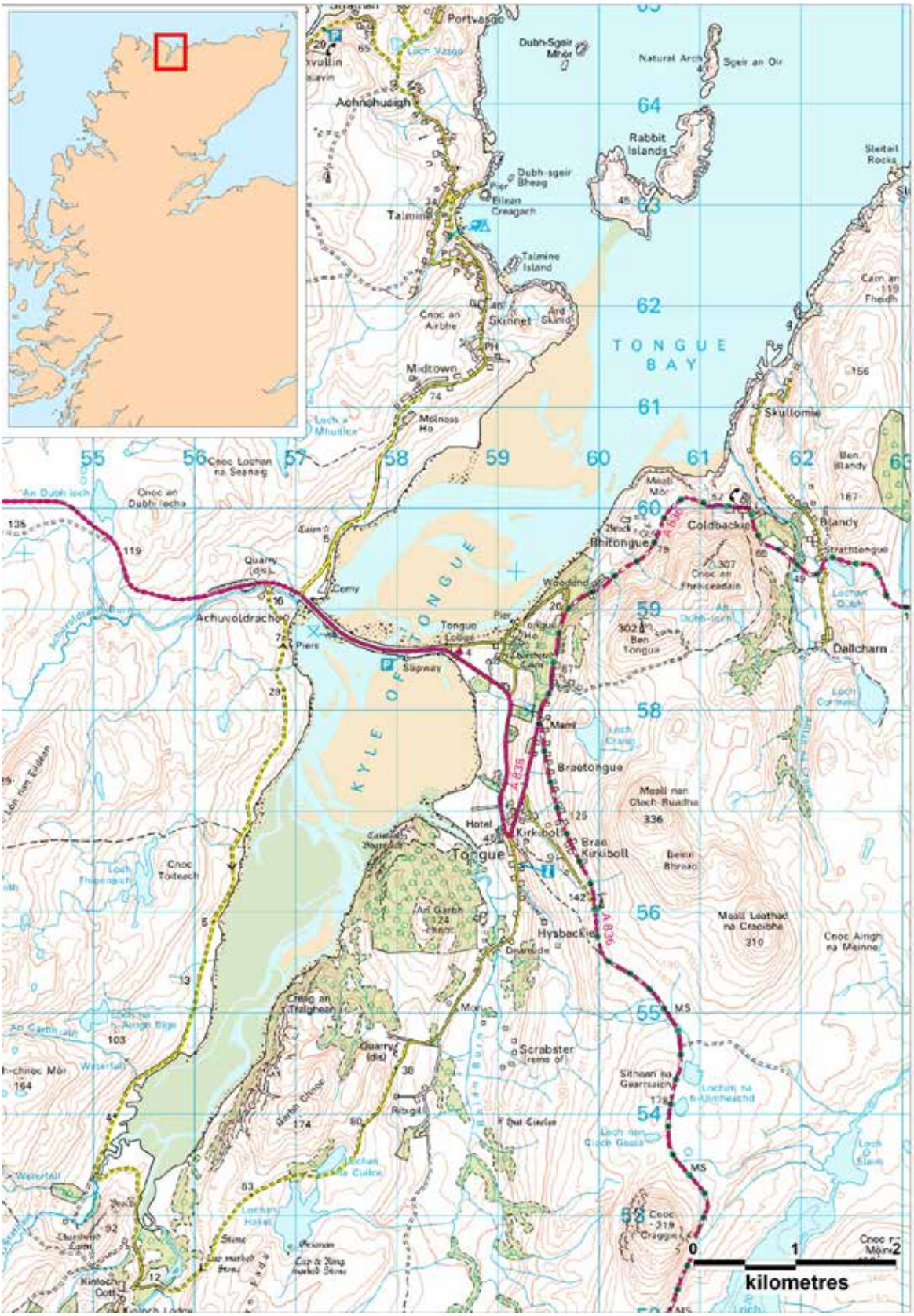


Figure 1.1 Location of Kyle of Tongue

2. Fishery

Pacific oysters (*Crassostrea gigas*) are cultured on trestles on an intertidal sandbar along the east side of the Kyle, just north of the causeway and at the southeastern extent of the production area. The area has been classified for production since 2001. Production area details are presented in Table 2.1.

Table 2.1 Kyle of Tongue fishery

Production area	Site	SIN	Species	RMP	Boundary
Kyle of Tongue	Kyle of Tongue	HS-103-303-13	Pacific Oyster	NC 5932 5902	Area bounded by lines drawn between NC 5977 6200 and NC 6211 6200, and between NC 5703 5900 and NC 5933 5898

The site currently has between 26 and 30 million oysters on 15000 trestles with an expectation to expand to 40 million.

This area has been previously been classified for the production of common mussels, common periwinkles and razor clams.

The location of the trestles recorded during the shoreline survey is plotted in Figure 2.1.

The current RMP is located approximately 120 metres east of the southern extent of the oyster trestle area observed in August 2013.

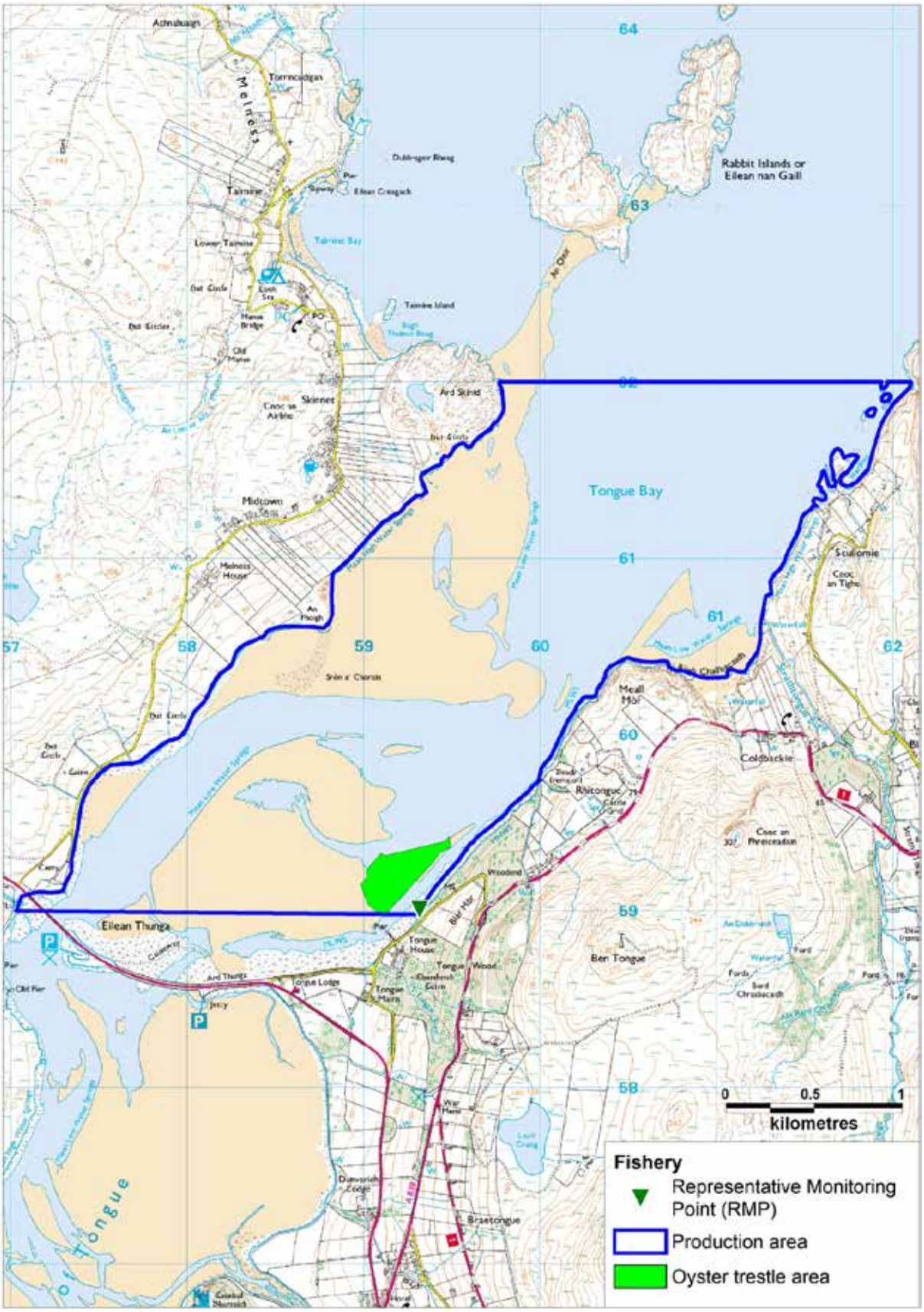


Figure 2.1 Kyle Of Tongue Fishery

3. Human Population

Information was obtained from the General Register Office for Scotland on the population within the census output areas in the vicinity of Kyle of Tongue. The last census was undertaken in 2011. The census output areas surrounding Kyle of Tongue are shown in Figure 3.1, thematically mapped by the 2011 population densities. The figure shows that the overall population density for the census output areas surrounding Kyle of Tongue is low. Information on the census output areas is presented in Table 3.1 below.

Table 3.1 Kyle of Tongue

Census output area no.	Total area (km^2)	Total population
S00082233	40	54
S00081011	5	121
S00081012	404	150
S00072803	24	62
S00081013	47	116

Roads run along most of the coast, with the majority of human population associated with crofting townships lining the roads. There are three main centres of population around the Kyles: the northwest shore around the townships of Midtown, Skinnet and Talmine, the southeast shore around Tongue and the east shore around Rhitongue, Coldbackie and Skullomie.

There is parking and a pier at either end of the A838 causeway across the Kyle. In addition, during the shoreline survey dwellings were observed at either end of the causeway. There are a campsite, slipway and pier identified on the Ordnance Survey map near Talmine on the northwestern coastline.

A youth hostel is located at the east end of the causeway and is open from April to the end of September (http://www.syha.org.uk/hostels-in-scotland/highlands/tongue.aspx). There are four hotels in Tongue, as well as other tourist accommodation. At least some of the hotels operate year-round. There is further holiday accommodation in and around Talmine.

Tongue has a primary school with approximately 30 students.

No commercial anchorages were identified on the Admiralty Chart for the area, however two yacht anchorages were noted in the cruising guide for the area (Clyde Cruising Club, 2003). One is located northeast of the oyster farm, near Skullomie and the other to the northwest in Talmine Bay.

Overall, inputs from human sources to the Kyle catchment are likely to be low but concentrated around the settlements of Tongue on the eastern shore and the three small villages on the northwestern shore. Given the low population, seasonal effects associated with the hotel and hostel may be proportionally high.

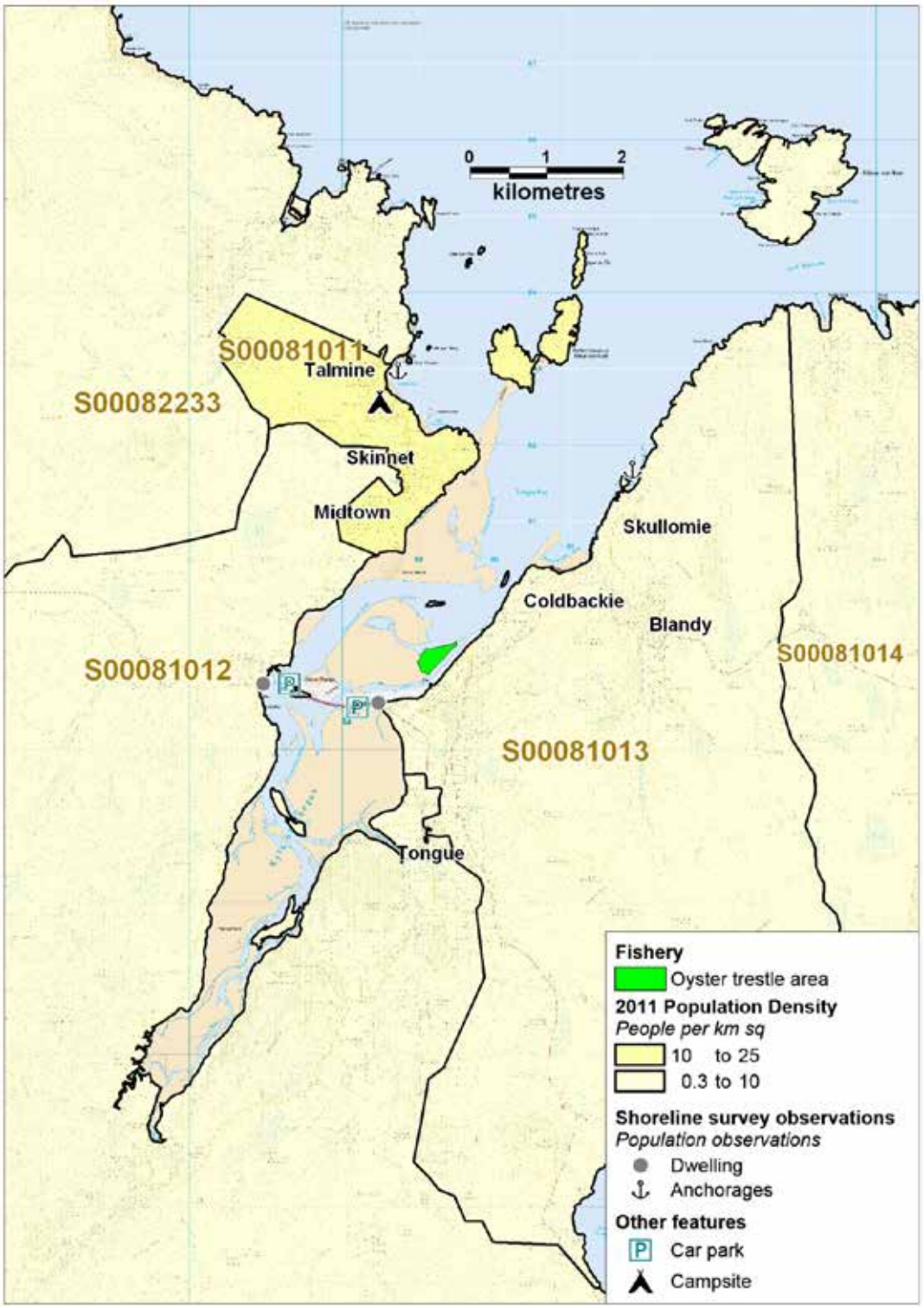


Figure 3.1 Population map for the area in the vicinity of Kyle of Tongue

4. Sewage Discharges

Information on sewage discharges for an area of radius 5.5 km around point NC 5930 6020 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, to waterbody or to sea), any available dispersion or dilution modelling studies, and whether improvements were in work or planned.

Four discharges were identified by Scottish Water for the area in question, as shown in Table 4.1.

Table 4.1 Scottish Water assets

Licence Number	Site Name	NGR	Discharge Type	Treatment Level	Max Daily Flow (m^3/d)	PE
CAR/L/1001895	Tongue Septic Tank	NC 5875 5665	Continuous	Septic tank	613	394
	Tongue CSO	NC 5875 5665	Intermittent	6mm screen	na	na
CAR/L/1002137	Melness Septic Tank	NC 5890 6250	Continuous	Septic tank	nr	360
	Melness CSO	NC 5890 6250	Intermittent	6mm screen	na	na
CAR/L/1087732	Lower Talmine WWPS EO	NC 5850 6270	Intermittent	6mm screen	na	na
nr	Coldbackie Septic Tank	NC 6110 6027	Continuous	Septic tank	nr	14

nr= not reported; na= not applicable; CSO= combined sewer overflow; EO= emergency overflow; WWPS= wastewater pumping station

The Tongue and Melness septic tanks have both the final effluent and CSO outfalls discharging to the same location. The Tongue and Coldbackie septic tanks were identified as "currently not prioritised for additional strategic capacity within the 2010-2015 investment period", whilst capacity at the Melness tank was noted as currently being sufficient for identified development needs.

4.1 Consented discharges (SEPA)

SEPA provided information of 63 discharges within the area requested. Five discharge consents did not appear to be related to sewage and so were not considered further here. Three of these were consents associated with water impoundment, a recycling centre, and engineering works. The remaining two

consents related to disposal of sheep dip to land. The rest of the data set is listed in Table 4.2.

Treatment type and receiving body information was missing for 23 different discharges. A further three consents had no receiving body information included. A follow-up enquiry was raised with SEPA but no response was received by the time of the submission of this report.

As there has historically been no requirement to register septic tanks in Scotland, it is highly likely that there are additional septic tank discharges in the area that have not yet been registered. SEPA have identified that in remote areas such as Highland Sutherland, some of the discharges identified as going to soakaway will have been rerouted by the property owner either to a watercourse or to sea upon failure of the soakaway field and therefore the number of discharges identified as being to water is likely to under represent the potential impact to water in this area.

The consented discharge is from the Tongue septic tank (CAR/L/1001895). It has a PE of 394 and a consented dry mean daily flow of ≤78.8 m^3/day. The final effluent from this septic tank discharges to a point below the normal tidal limit (NTL) of Rhian Burn, which flows into the Kyle of Tongue upstream of the production area.

Data on two other public discharges were given: CAR/L/1002137 which is a STW and CAR/L/1087732 which is a combined sewer overflow. The reported PE given for this tank was 1; however it is highly likely that this is not an accurate reflection of the size of this discharge. No flow data or receiving body data was provided, this was queried with SEPA but no response had been received by this reports submission. It is likely the treatment works discharge to Tongue Bay and could have an impact on the production area.

The Coldbackie septic tank listed in the Scottish Water documents was not included in the data provided by SEPA.

Data for twenty-three discharges included no treatment type or receiving body information, however population equivalents (PE) were given. These consents are therefore assumed to be sewage discharges.

Twenty eight consents were recorded as discharging to land, two to the Kyle of Tongue and two to watercourses flowing into the Kyle.

Table 4.2 SEPA discharge consents

Licence number	NGR	Site Name	Discharge Type	Discharges to	DWF m^3/d	PE
CAR/L/1001895	NC 58807 56655	STW, Tongue, Lairg	STW	Rhian Burn (below NTL)	≤78.8	394
CAR/L/1002137	NC 58832 62422	Melness	STW	Talmine Bay (NC 5890 6250)	-	360
WPC/N/0054457	-	Coldbackie Septic Tank	Septic Tank	Soakaway (probable)	-	-
CAR/R/1099359	NC 57040 58820	Ferry House Tongue, Lairg	Sewage (Private) Untreated	Kyle of Tongue	-	6
CAR/L/1087732	NC 58570 62560	Tongue Sewerage Network	Combined Sewer Overflow (CSO)	-	-	-
CAR/R/1009369	NC 58510 58520	Tongue Youth Hostel, BY LAIRG	Septic Tank	Kyle of Tongue	-	14
CAR/R/1017033	NC 59912 59212	Woodend, Lairg	Sewage (Private) Primary	U/N W/C	-	5
CAR/R/1016377	NC 61972 59567	Strathtongue, Tongue	Sewage (Private) Secondary	Strathtongue Burn	-	5
CAR/R/1046843	NC 59480 58074	Braetongue, Tongue, By Lairg	Sewage (Private) Primary	Soakaway	-	<50
CAR/R/1008958	NC 58228 62136	Talmine, Sutherland	-	-	-	6
CAR/R/1009619	NC 61830 61220	Scullmonie, Tongue	Septic Tank	Soakaway	-	5
CAR/R/1010183	NC 59190 55940	Inchverry, Tongue	Septic Tank	Soakaway	-	5
CAR/R/1010488	NC 58200 64020	Talmine, Lairg	Septic Tank	Soakaway	-	5
CAR/R/1012004	NC 61520 60880	Scullomie, Tongue	Sewage (Private) Primary	Soakaway	-	5
CAR/R/1012865	NC 58362 64844	Port Vasgo, Talmine, Lairg	Septic Tank	Soakaway	-	5
CAR/R/1016669	NC 60500 59850	Rhitongue, Tongue, By Lairg	Sewage (Private) Primary	Soakaway	-	5
CAR/R/1017032	NC 59955 59214	Woodend, Lairg	-	-	-	5
CAR/R/1018426	NC 59934 59148	Rhitongue, Lairg	-	-	-	5
CAR/R/1020523	NC 58816 55546	Tongue, Lairg	Sewage (Private) Secondary	Soakaway	-	6
CAR/R/1021742	NC 59270 57600	Brae Tongue, Lairg	-	-	-	5
CAR/R/1021985	NC 61954 59965	Blandy, Tongue	Sewage (Private) Primary	Soakaway	-	5

Licence number	NGR	Site Name	Discharge Type	Discharges to	DWF m^3/d	PE
CAR/R/1022617	NC 62129 59615	New House, S Eilean Ron, Strathtongue	Sewage (Private) Primary	Soakaway	-	8
CAR/R/1029573	NC 58383 64931	Port Vasgo, Talmine	-	-	-	5
CAR/R/1044311	NC 58860 55951	Tongue, Lairg	Sewage (Private) Primary	Soakaway	-	6
CAR/R/1045393	NC 58532 55117	Firclis, Tongue, Lairg	-	-	-	5
CAR/R/1048017	NC 58180 60900	Mid Town, Melness,Lairg	Sewage (Private) Primary	Soakaway	-	5
CAR/R/1048898	NC 60269 59872	Rhitongue,Tongue,Lairg	-	-	-	5
CAR/R/1049341	NC 62175 58639	Dalcharn,Tongue,Lairg	-	-	-	5
CAR/R/1050314	NC 61630 61150	Scullomie, Tongue, Lairg	Sewage (Private) Secondary	Soakaway	-	5
CAR/R/1056775	NC 61850 61200	Scullomie, Tongue, Sutherland	-	-	-	5
CAR/R/1056884	NC 61481 60841	Scullomie, Tongue, Sutherland	Sewage (Private) Primary	Soakaway	-	6
CAR/R/1057842	NC 58414 64849	Portvasgo, Burnside,	Sewage (Private) Primary	Soakaway	-	5
CAR/R/1059061	NC 61850 61240	Scullomie, Tongue, Lairg	Sewage (Private) Primary	Soakaway	-	5
CAR/R/1059858	NC 61968 60026	Blandy, Tounge, Lairg	-	-	-	6
CAR/R/1064488	NC 59163 56329	Tongue, Lairg, Sutherland	-	-	-	5
CAR/R/1065238	NC 57113 64524	Talmine, Melness, Lairg	Sewage (Private) Primary	Soakaway	-	5
CAR/R/1065550	NC 56396 63980	Talmine, Lairg	-	-	-	5
CAR/R/1065968	NC 57012 64832	Achininver, Tamline, Lairg	Sewage (Private) Primary	Soakaway	-	5
CAR/R/1066266	NC 56270 63630	West Strathan, Talmine	Sewage (Private) Primary	Soakaway	-	5
CAR/R/1067147	NC 62160 59660	Strath, Tongue, Lairg	Sewage (Private) Primary	Soakaway	-	5
CAR/R/1067213	NC 59225 56242	Tongue, Lairg, Sutherland	-	-	-	8
CAR/R/1069134	NC 58797 55419	Rhian, Tongue, Lairg, Sutherland	-	-	-	5
CAR/R/1069230	NC 56608 64503	West Strathan, Talmine, Lairg	Sewage (Private) Primary	Soakaway	-	5
CAR/R/1069725	NC 59953 59228	Woodend, Tongue	Sewage (Private) Primary	Soakaway	-	5
CAR/R/1076444	NC 60047 59319	Rhitongue, Tongue, by Lairg, Sutherland	Sewage (Private) Primary	Soakaway	-	5

Licence number	NGR	Site Name	Discharge Type	Discharges to	DWF m^3/d	PE
CAR/R/1076925	NC 61946 61399	Scullomie, Tongue	-	-	-	5
CAR/R/1077107	NC 57973 64194	Crossroads, Talmine, By Lairg	-	-	-	5
CAR/R/1077394	NC 59164 56481	The Village, Tongue	-	-	-	5
CAR/R/1077419	NC 59452 57788	Braetongue, Tongue	Sewage (Private) Primary	Soakaway	-	6
CAR/R/1077576	NC 58570 63654	Achnahuaigh, Talmine, Lairg	-	-	-	5
CAR/R/1077767	NC 57650 64750	Strathmelness, Talmine, Tongue, Lairg	Sewage (Private) Primary	Soakaway	-	5
CAR/R/1078439	NC 57660 64810	East Strathen, Talmine, Lairg	Sewage (Private) Primary	Soakaway	-	5
CAR/R/1078490	NC 58330 64913	Portvasgo, Talmine, By Lairg	Sewage (Private) Primary	Soakaway	-	5
CAR/R/1085333	NC 59107 55800	Rhian, Tongue	-	-	-	6
CAR/R/1092327	NC 61770 61170	Scullomie, Tongue	-	-	-	5
CAR/R/1100409	NC 62276 58790	Dalcharn, Tongue, Lairg	-	-	-	5
CAR/R/1103747	NC 58441 64931	Portvasgo, Talmine, Sutherland	Sewage (Private) Primary	Soakaway	-	5
CAR/R/1104511	NC 59788 58204	Braetongue, Tongue, Lairg	-	-	-	5
CAR/R/1106042	NC 61807 61141	Scullomie, Tongue	-	-	-	5

- No data provided PE=Design Population Equivalent DWF=Dry Weather Flow

The two consents discharging directly to the Kyle both discharge at the causeway. CAR/R/1009369, associated with a youth hostel, discharges septic tank effluent to the eastern end of the causeway and has a consented PE of 14. CAR/R/1099359, discharges raw effluent to the western end of the causeway and has a consented PE of 6. SEPA report that the consent for this discharge contains conditions requiring upgraded treatment and that they will be reviewing progress made on the upgrade in the near future.

The two watercourses which receive effluent from discharge consents both flow into the production area. CAR/R/1017033 discharges septic tank effluent to an unnamed watercourse which flows into the production area less than 400 m from the nearest trestle. The septic tank has a consented PE of 5. CAR/R/1016377 discharges septic tank effluent to Strathtongue Burn. This also has a consented PE of 5.

Shoreline Survey Discharge Observations

Three observations of sewage infrastructure or evidence of sewage discharge were noted during the shoreline surveys. These are listed in Table 4.3 below.

Table 4.3 Discharge-associated observations made during the shoreline survey

No.	Date	NGR	Associated Photograph (Appendix 5)	E. coli cfu/100ml	Description
1	20/08/2013	NC 5697 5887	Fig. 8		Pipe running to shore from beside house. Pipe is dry with no flow and has 10cm diameter. No septic tank visible.
2	20/08/2013	NC 5909 5880	Fig. 11	600000	Metal pipe, situated next to pier, running down onto shore from a property behind. Evidence of raw sewage coming from the pipe. Very strong bad smell.

Observation 1 reports a pipe running to shore from a house. This observation appears to relate to CAR/R/1099359, an untreated private sewage discharge. The pipe had no flow at the time of the survey and therefore it is not clear whether it is still in use.

Observation 2 reports a metal pipe discharging raw sewage to the shore directly adjacent to the fishery at a rate of 6 ml/s. A sample taken from this discharge returned a high result of 600000 *E. coli*/100 ml. Assuming a constant flow and *E. coli* level the *E. coli* loading on the loch would be from this source would be 3.6×10^9 *E.coli*/day.

Summary

The area surrounding the production area is moderately populated. The majority of sewage discharge consents report effluent going to land via soakaway but two

discharges are reported as discharging to watercourses flowing into the production area, and two consents discharge into the Kyle upstream of the production area.

Three community discharges were reported which appear to serve at least parts of the largest communities in the area. It is not clear where effluent from these discharges. It is likely that they discharge either to sea or a watercourse: if so, they could have an impact on the fishery. This in particular applies to Tongue septic tank which would discharge to the tidal reaches of Rhian Burn and the Coldbackie septic tank, which would discharge to the northeast of the oyster farm.

The discharges located within a short distance of the south of the oyster trestles are likely to have the most immediate impact on the water quality in that location.

Acronyms

CSO	Combined Sewer Overflow
DWF	Dry Weather Flow
MDF	Mean Daily Flow
PE	Population Equivalent
ST	Septic Tank

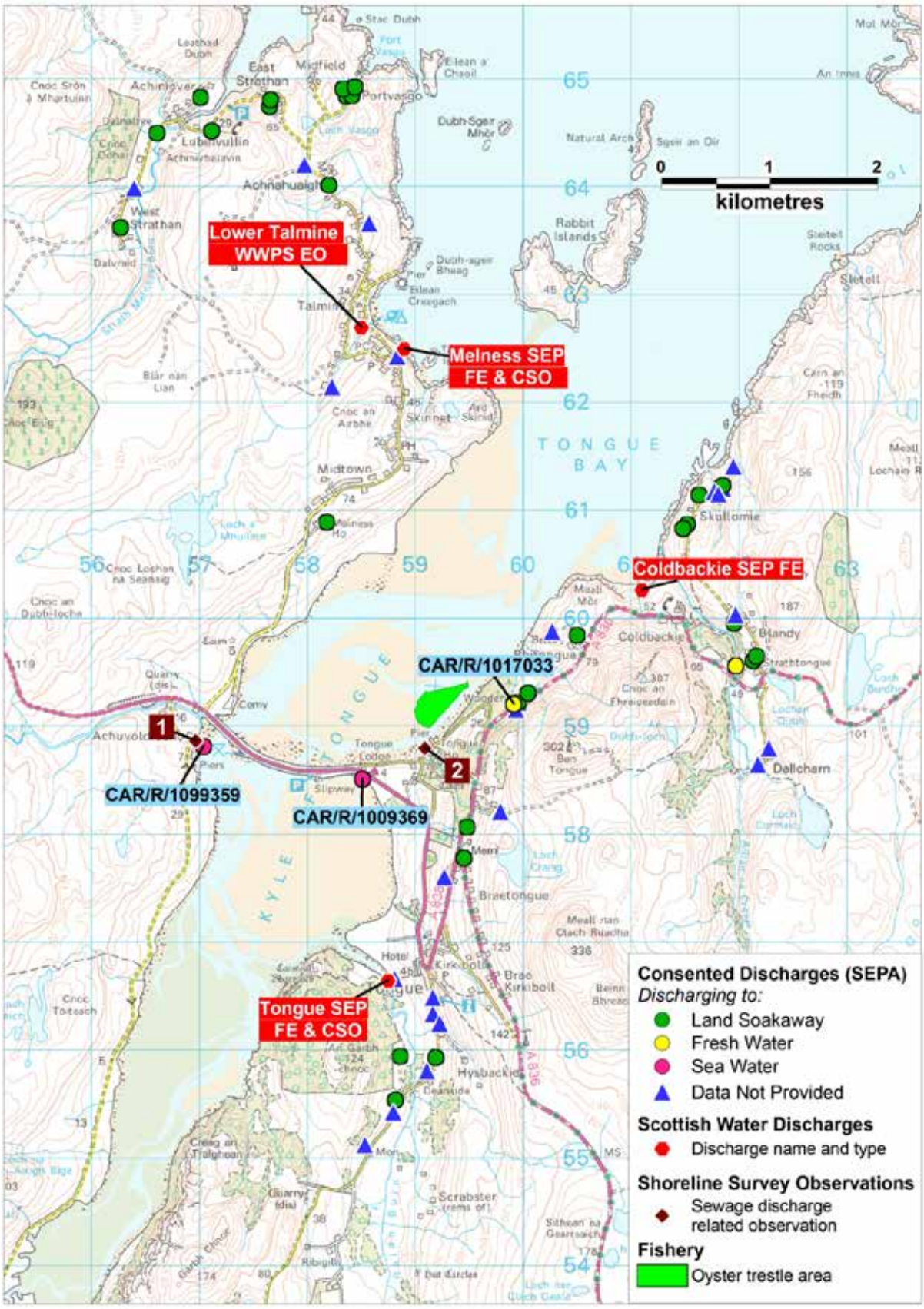


Figure 4.1 Map of discharges for Kyle of Tongue

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 Harris parish. Reported livestock populations for the parish 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 Tongue agricultural parish 2012

	Tongue 347 km^2	
	Holdings	Numbers
Poultry	13	245
Cattle	29	241
Sheep	50	8246
Other horses and ponies	10	18

The livestock census numbers relate to a large parish area (covering 347 km^2), therefore it is not possible to determine the spatial distribution of the livestock in relation to the Kyle of Tongue area or identify how many animals are likely to impact the catchment around the fishery. The figures do give an idea of the total numbers of livestock over the broader area. Sheep are the dominant livestock in the parish. Poultry, cattle and other horses and ponies are present in low numbers. A source of spatially relevant information on livestock population in the area was the shoreline survey (see Appendix 5) which only relates to the time of the site visit on the 20th August 2013 (see Table 5.1). Observations made during the survey are dependent upon the viewpoint of the observer some animals may have been obscured by the terrain. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 5.1.

During the survey, in addition to sheep droppings and tracks approximately 35 sheep in total were observed grazing along the north western shoreline. Although no sheep were recorded from the eastern shoreline, sheep were visible on improved pasture around Tongue, Coldbackie and Skullomie in internet-based satellite images for the area (http://www.bing.com/maps/, viewed 17/11/2013). No animals were seen on shoreline immediately adjacent to the oyster farm during the shoreline survey. Numbers of sheep will be approximately double during late spring following the birth of lambs, and decrease again in the autumn when they are sent to market.

Any impacts to water quality at the fishery will be concentrated along the eastern shore where there are sheep on pasture areas, to the south of the oyster farm around the causeway and north of the oyster farm around Rhitongue and Coldbackie. There will be less likelihood of contamination arising from sheep on the western shoreline impacting at the fishery.

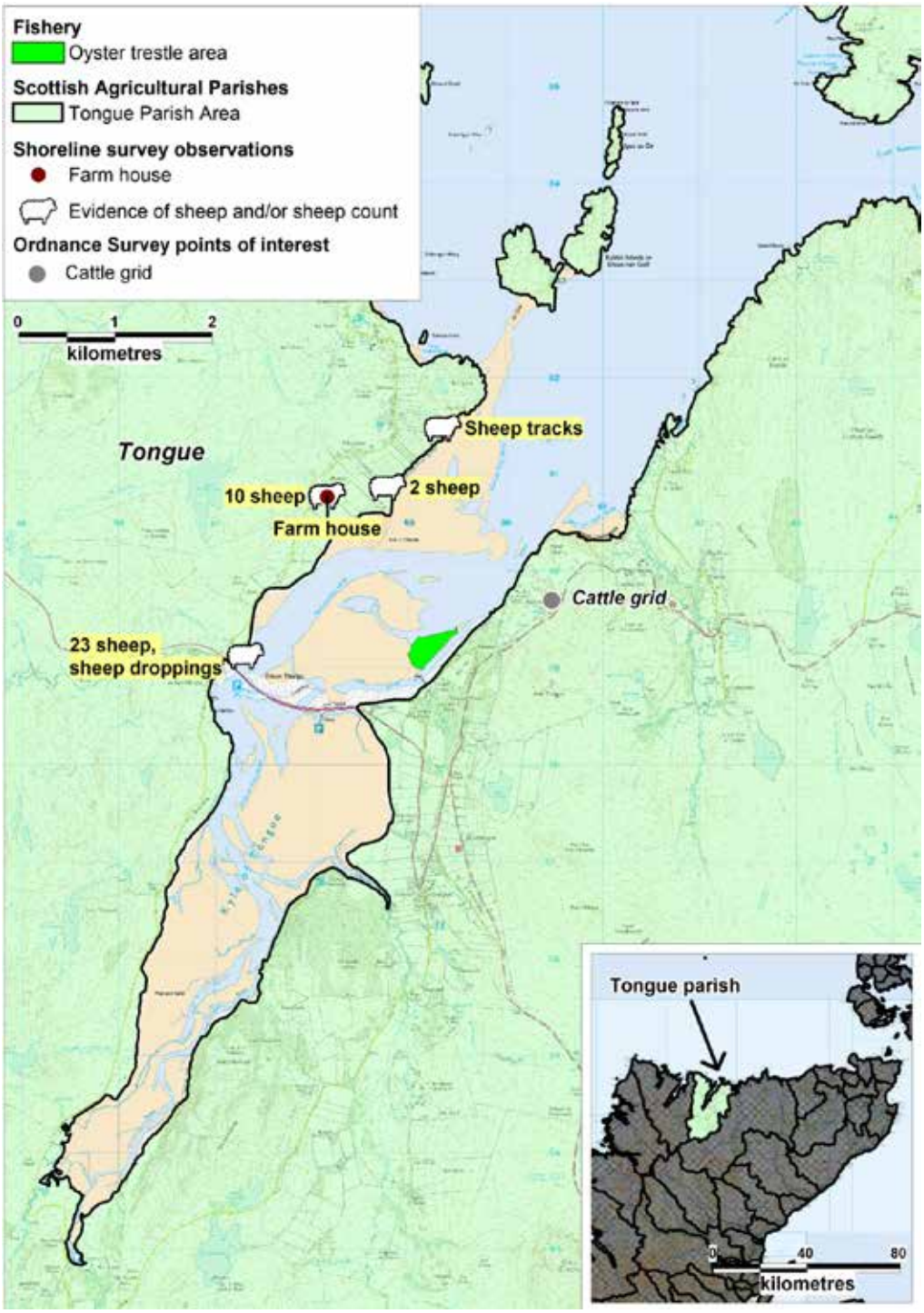


Figure 5.1 Agricultural parish boundary and livestock observations at Kyle Of Tongue

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 Kyle of Tongue Pacific oyster fishery are considered below.

Pinnipeds

In a report by the Scottish Committee on Seals (2012), it was highlighted that roughly 20 harbour seals used the head of Kyle of Tongue between 2007 and 2011. Over the same period grey seals were in far greater abundance, with approximately 100 seals using an area <10 km northwest of Kyle of Tongue and 20 seals using the head of the Kyle of Tongue. It should be noted that Eilean nan Ron (Gaelic for Seal Island) is located approximately 6 km northeast of Kyle of Tongue, and has had a long established breeding colony of grey seals (Undiscovered Scotland, 2013). The area to the west around Cape Wrath is also recognised as an important area for grey seals as well (Special Committee on Seals, 2012), with harbour seals also shown to use the area. Seals are therefore likely to be in high abundance in waters around Kyle of Tongue.

No seals were observed during the shoreline survey.

Cetaceans

The northwest of Scotland is recognised as an area that supports a large number of cetacean species (Sea Watch Foundation, 2007), varying from whales to harbour porpoise. Due to the shallow nature of the Kyle of Tongue, it is unlikely that cetaceans will navigate into the area. However, in a study by Dolman *et al.,* (2010) it was recorded that two large dead cetaceans; a pilot whale and a Cuvier's beaked whale were found washed up in the Kyle of Tongue between January and July 2008.

Birds

Seabird 2000 census data (Mitchell, et al., 2004) for the area within a 5 km radius of Kyle of Tongue was obtained and is summarised in Table 6.1. This census, undertaken between 1998 and 2002 covered twenty five species of seabird that breed regularly in Britain and Ireland.

Table 6.1 Seabird counts within 5 km of the Kyle of Tongue

Common name	Species	Count	Method*
European storm petrel	*Hydrobates pelagicus*	688	Occupied Sites
Great black-backed gull	*Larus marinus*	384	Occupied Nests and Territory
European herring gull	*Larus argentatus*	92	Occupied Nests and Territory
Lesser black-backed gull	*Larus fuscus*	4	Occupied Nests
Northern Fulmar	*Fulmarus glacialis*	4266	Occupied Sites
European Shag	*Phalacrocorax aristotelis*	106	Occupied Nests
Great cormorant	*Phalacrocorax carbo*	40	Occupied Nests
Razorbill	*Alca torda*	42	Individuals on Land
Atlantic puffin	*Fratercula arctica*	1	Individuals on Land
Parasitic jaeger	*Stercorarius parasiticus*	8	Occupied Territory
Great skua	*Stercorarius skua*	42	Occupied Territory
Arctic tern	*Sterna paradisaea*	680	Occupied Territory
Black guillemot	*Cepphus grylle*	72	Individuals on Land
Black legged kittiwake	*Rissa tridactyla*	138	Occupied Nests

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

There are dense concentrations of seabirds located at the head of Kyle of Tongue at Rabbit Island and further offshore on Eilean nan Ron. Birds include both resident and migratory species. These dense concentrations of bird colonies are located >4 km from the current fishery at the Kyle of Tongue. A Northern fulmar site lies approximately 3.5 km northeast of the oyster trestles, with six individual black guillemots also recorded in the near vicinity. The Northern fulmar breeding season is between April and September, with one chick born per pair (Robinson, 2005). A site of lesser black-backed gulls is also situated <2 km west of the fishery. Clutch size can be as big as three eggs with the breeding season between late July and September.

A number of conservation areas that include references to birds are also located in the vicinity of the Kyle of Tongue. North Sutherland Coastal Islands SPA encompasses Eilean nan Ron and is recognised for its breeding colonies of gulls and overwintering flocks of Greenland barnacle geese. These birds use both the habitats on the island and mainland areas in the close vicinity, particularly agricultural pasture/grassland. Caithness and Sutherland Peatlands is designated as a RAMSAR, SPA and SAC site and lies inland at the head of the Kyle of Tongue. Although primarily recognised for habitats, it is also an important area for various species of waterfowl and wading birds.

During the shoreline survey, birds were the only wildlife observed. Species included gulls and geese, which were the most numerous, oystercatchers, herons and a pigeon. All geese observed were in flight over agricultural land on the northwest of the area. Gulls were seen on shore and at sea, with the majority seen on the eastern and southern sides of the survey area.

Deer

There is anecdotal evidence of red deer on land surrounding Kyle of Tongue (Picture the UK, 2013). No estimations on populations in the surrounding area were found.

Otters

The Eurasian Otter (*Lutra lutra*) is recognised as a qualifying feature in the Caithness and Sutherland Peatlands SAC. No population estimations were available at the time of this report. However this SAC is also designated for the important habitats in the area, which are thought to be suitable to support populations of otters.

Overall

It is likely that seabirds and seals will have the most significant contamination impact on the fishery at Kyle of Tongue. The effect of seabirds will be greatest with the largest populations being located towards the mouth of the Kyle. The impact from seals is expected to vary considerably.

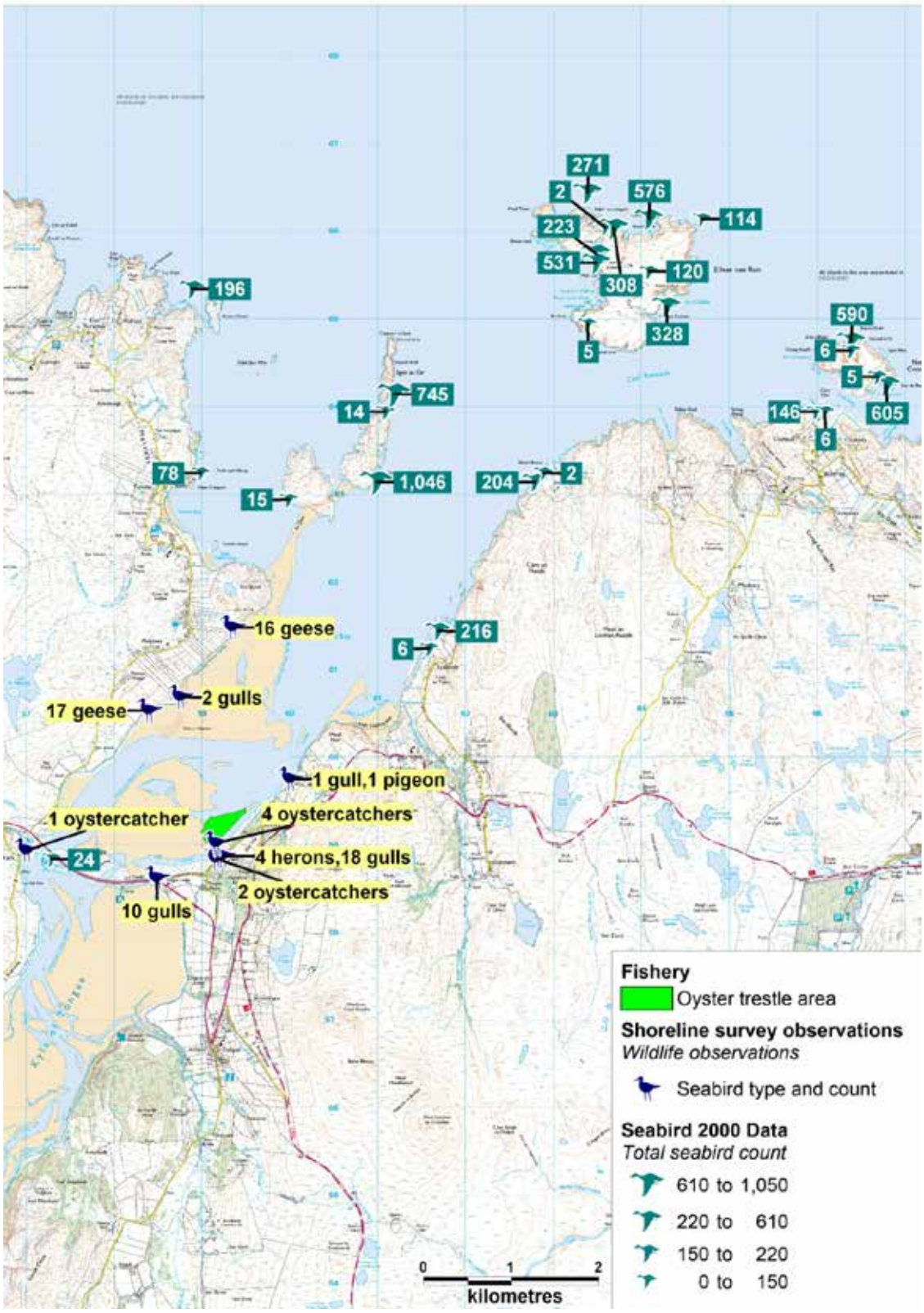


Figure 6.1 Location of wildlife around Kyle of Tongue

7. Land Cover

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

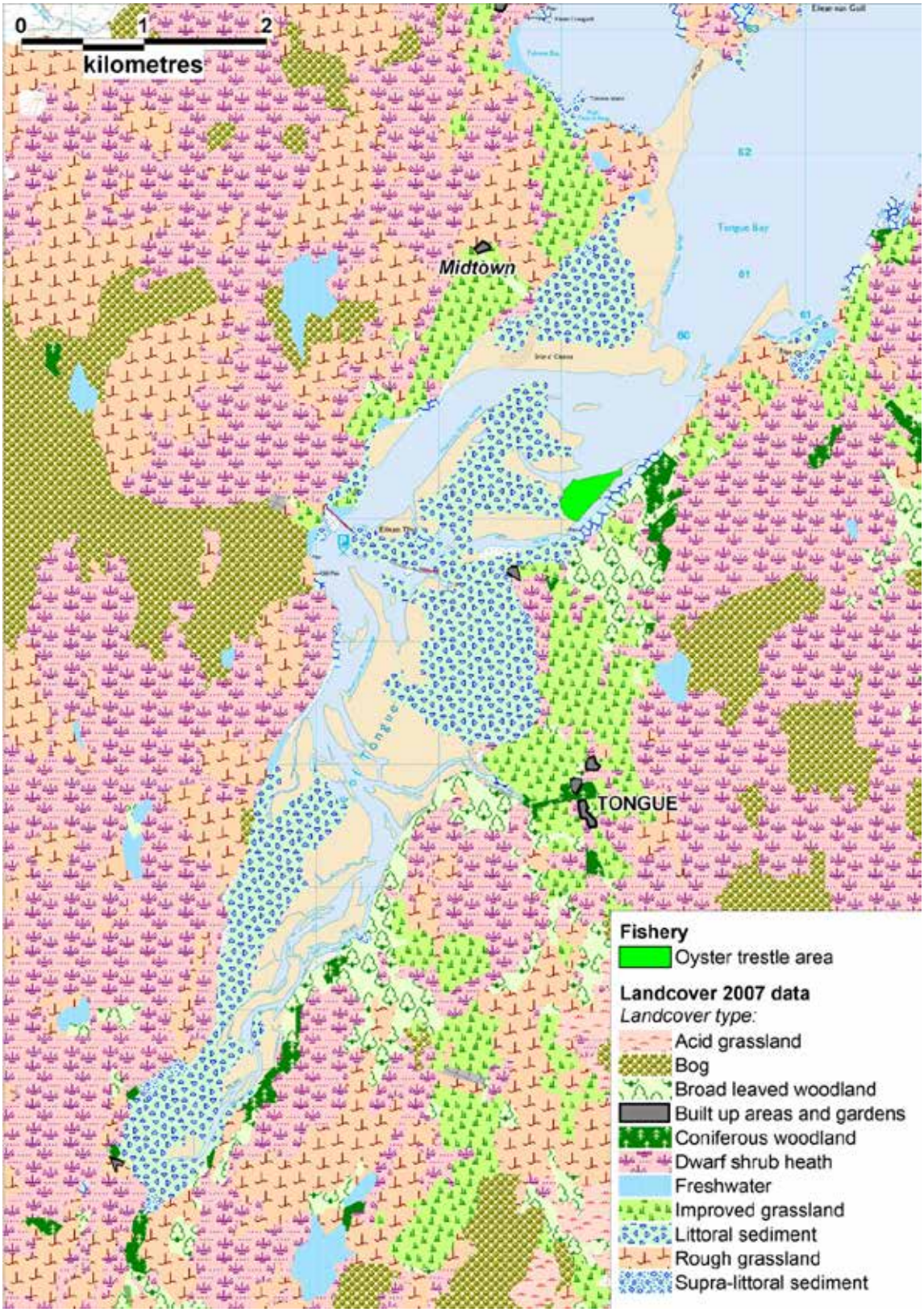


Figure 7.1 LCM2007 land cover data for the area around Kyle of Tongue

Dwarf shrub heath, improved grassland, rough grassland and bog are the predominant land cover types on the shoreline adjacent to the Kyle of Tongue fishery. There are also smaller areas of coniferous and broadleaved woodland and acid grassland. The areas of improved grassland are situated on the eastern and western shorelines adjacent to the fishery. Parts of the settlements of Tongue and Midtown are shown as “Built up areas and gardens”.

Faecal indicator organism export coefficients for faecal coliform bacteria have been found to be approximately 1.2 – $2.8x10^9$ cfu/km^2/hr for urban catchment areas, approximately $8.3x10^8$ cfu/km^2/hr for areas of improved grassland and approximately $2.5x10^8$ cfu/km^2/hr for rough grazing (Kay, et al., 2008). The contributions from all land cover types would be expected to increase significantly after rainfall events, however this effect would be particularly marked from improved grassland areas (roughly 1000-fold) (Kay, et al., 2008).

The highest potential contribution of contaminated run-off to the Kyle of Tongue fishery is from the small built up areas on the eastern and north-western sides of the Kyle and also from the areas of improved grassland located along the north-eastern, south-eastern and eastern shorelines at the eastern extent of the oyster farm. Contamination is likely to be significantly higher after rainfall.

8. Watercourses

There are no gauging stations on watercourses entering into the Kyle of Tongue.

Information on flows and microbial content was only available from the shoreline survey conducted on the 20th and 21st August 2013. Some rainfall was recorded in the evening of the first day, but no other rainfall was recorded during, or in the 48 hrs prior to the survey. The seven watercourses listed in Table 8.1 are noted to be the most significant freshwater inputs to the Kyle of Tongue area.

At the time of the survey, a freshwater sample was not taken at watercourse 5. Three areas of land drainage were also noted, but flow was not sufficient enough to be sampled. All freshwater observations noted during the survey are displayed in Figure 8.1.

Table 8.1 Watercourses entering Kyle of Tongue

No.	Description	NGR	Width (m)	Depth (m)	Flow (m^3/d)	*E. coli* (cfu/ 100 ml)
1	Unnamed watercourse	NC 5934 6148	0.44	0.05	280	$2.8x10^9$
2	Achuvoldrach Burn	NC 5704 5905	3.50	0.34	9600	$1.3x10^{11}$
3	Strathtongue Burn	NC 6126 6063	0.43	0.09	5300	$1.6x10^9$
4	Tongue Burn	NC 5904 5870	0.75	0.10	32.4	$2.0x10^8$
5	Unnamed watercourse	NC 5959 5930	0.60	0.02	0.864	Not Determined
6	Unnamed watercourse	NC 5994 5963	0.75	0.10	91	$3.0x10^8$
7	Unnamed watercourse	NC 6000 5975	1.10	0.10	960	$3.1x10^9$

The highest loading enters from Achuvoldrach Burn, approximately 2.1 km west of the fishery $1.3x10^{11}$ *E. coli* per day. Four watercourses enter into the Kyle within 1 km from the current location of the oyster fishery. Although one of these watercourses could not be sampled at the time of the survey, loadings calculated for the other three ranged from $2.0x10^8$ to $3.1x10^9$ *E. coli* per day. During or following periods of heavy rainfall it is expected that loadings from these watercourses will increase, owing to both human and wildlife sources in the catchment area. Contamination from Tongue Burn is most likely to affect the southeast extent of the fishery, whilst contamination from watercourse numbers 5-7 are expected to mostly impact the northeast extent of the fishery.

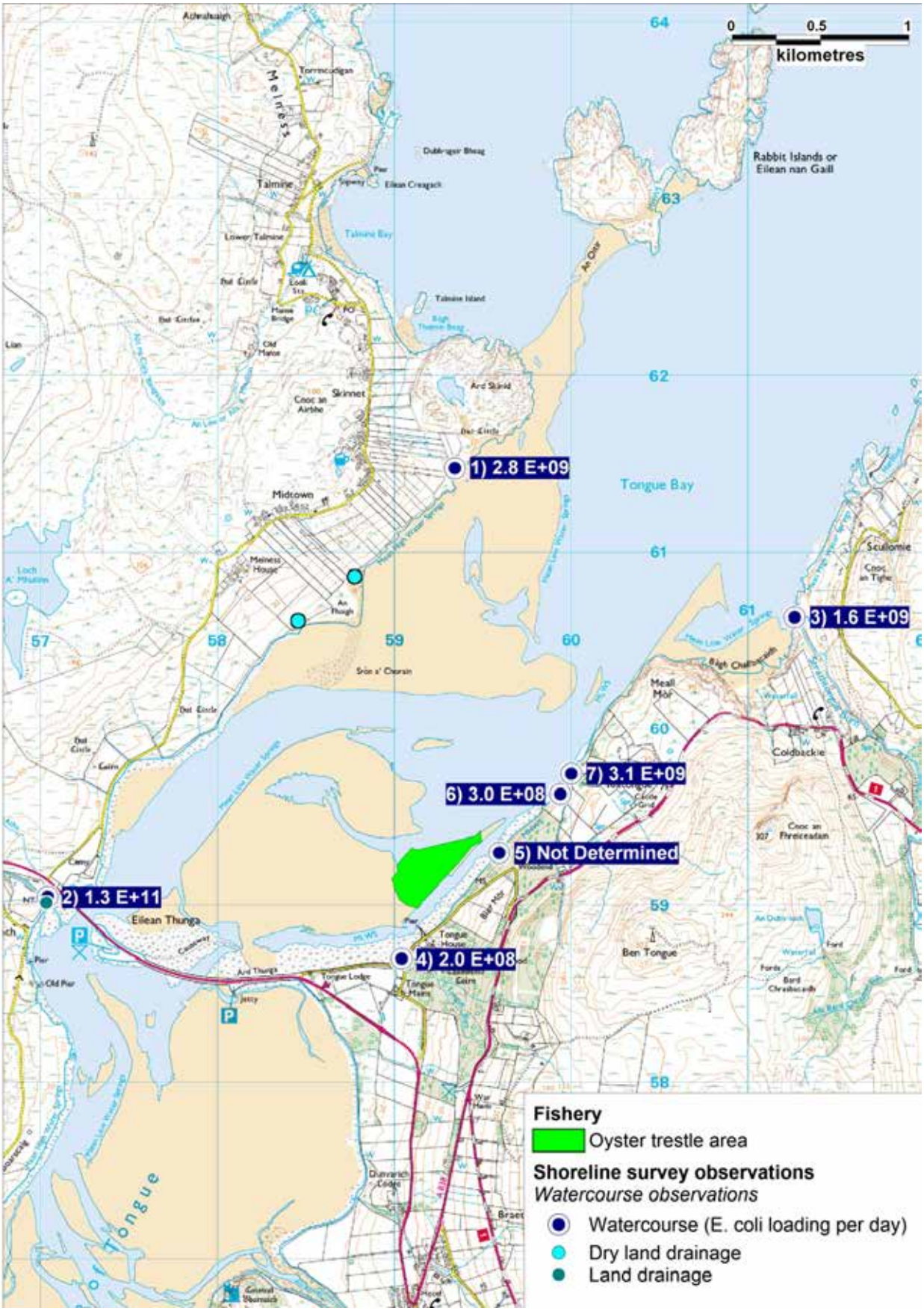


Figure 8.1 Map of watercourse loadings at Kyle of Tongue

9. Meteorological Data

The nearest weather station for which a nearly complete rainfall data set was available is located at Achfary, situated approximately 34 km to the southwest of Kyle of Tongue. Rainfall data was obtained for this station for the period 1 January 2007 to 31 December 2012. The nearest wind station is situated at Wick Airport, located 75 km east of the production area, however data from Stornoway Airport (located 120 km south west of the fishery) has been used instead as this captured the dominating south west airflow for this area of Scotland. Conditions may differ between this station and the fisheries due to the distances between them. However, this data is still shown as it can be useful in identifying seasonal variation in wind patterns.

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

9.1 Rainfall

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

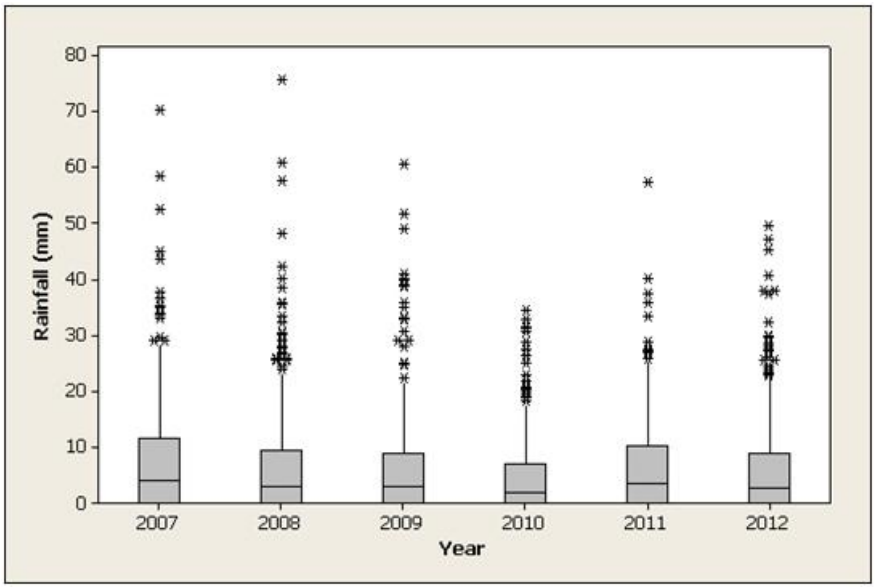


Figure 9.1 Box plot of daily rainfall values by year at Achfary (2007 – 2012)

Total rainfall values varied from year to year, with 2010 being driest year (a total of 1719 mm). The wettest year was 2007 (a total of 2554 mm). High daily rainfall values of more than 30 mm/day occurred in all years. Rainfall of greater than 70 mm/day was recorded on two occasions, in 2007 and 2008.

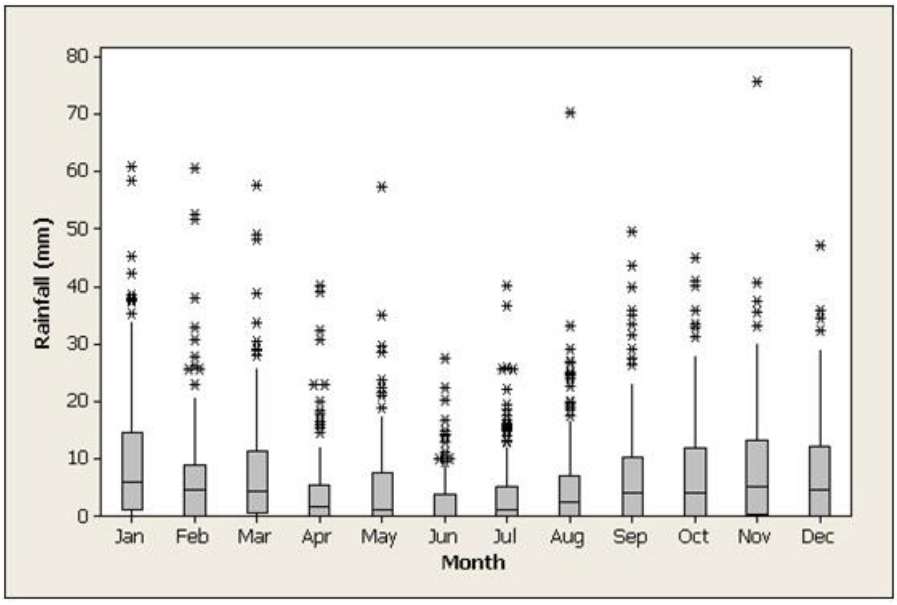


Figure 9.2 Box plot of daily rainfall values by month at Achfary (2007 – 2012)

Rainfall was lowest between April and August and highest between September and March. Rainfall values exceeding 30 mm/d were seen in all months apart from June. The extreme daily rainfall events of >70 mm occurred in August and November.

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

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

9.2 Wind

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

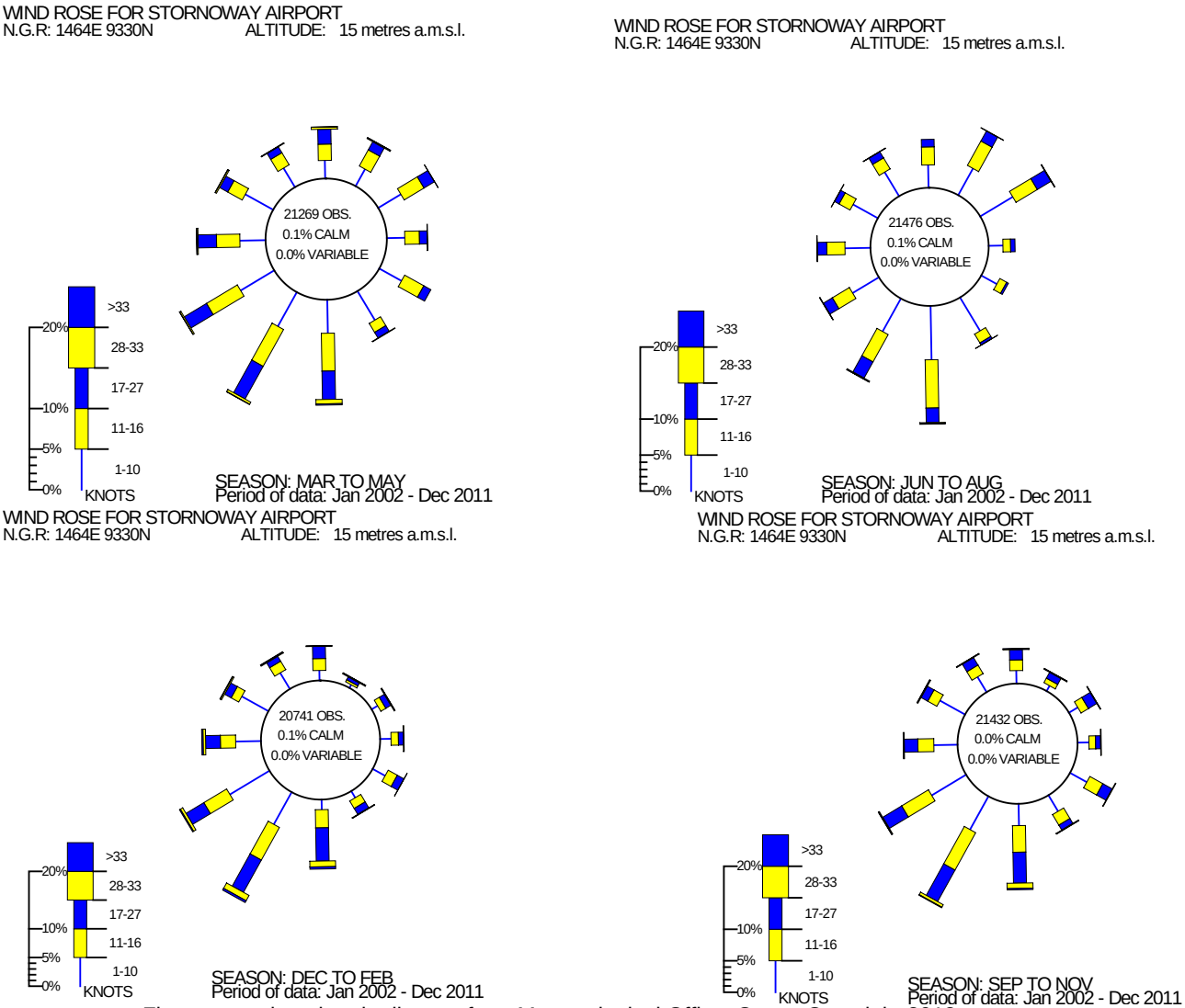


Figure reproduced under license from Meteorological Office. Crown Copyright 2012.

Figure 9.3 Seasonal wind roses for Stornoway Airport

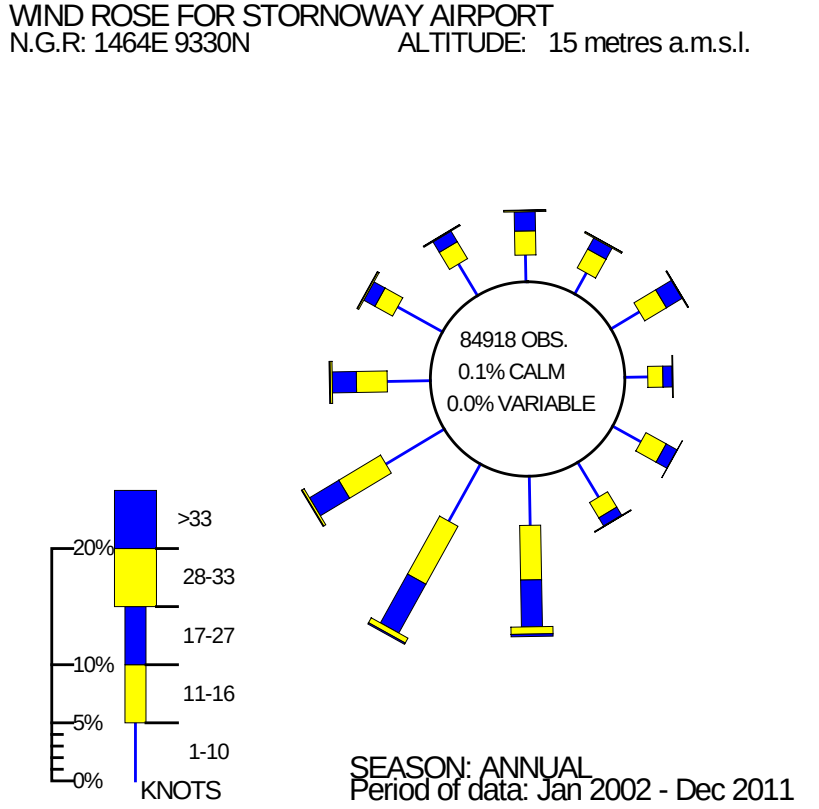


Figure 9.4 Annual wind rose for Stornoway Airport

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

10. Classification Information

Kyle of Tongue has been classified for production of Pacific oysters (*Crassostrea gigas*) since 2001. The classification history since 2008 is listed in Table 10.1. The area has been consistently classified as A since January 2009.

Table 10.1 Kyle of Tongue classification history

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

11. Historical *E. coli* Data

11.1 Validation of historical data

Results for all samples assigned against the Kyle of Tongue site for the period 01/01/2008 to the 24/10/2013 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 24/10/2013. 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 *E. coli* MPN/100 g were reassigned a value of 10 *E. coli* MPN/100 g for the purposes of statistical evaluation and graphical representation.

Four samples were reported as rejected and were deleted from further analysis. One sample lay >100 m outside of the production area, on land and was excluded from further statistical analyses. The remaining 65 results were delivered within the 48 hr delivery window, with box temperatures of <8^{o}C.

11.2 Summary of microbiological results

Table 11.1 Summary of historical sampling and results

Sampling Summary	
Production area	Kyle of Tongue
Site	Kyle of Tongue
Species	Pacific oysters
SIN	HS-103-303-13
Location	Various
Total no of samples	65
No. 2008	11
No. 2009	11
No. 2010	12
No. 2011	10
No. 2012	12
No. 2013	9
Minimum	<20
Maximum	700
Median	20
Geometric mean	25
90 percentile	118
95 percentile	300
No. exceeding 230/100g	3 (5%)
No. exceeding 1000/100g	0
No. exceeding 4600/100g	0
No. exceeding 18000/100g	0

The majority of results have been low, with the 90 percentile calculated at 118 *E. coli* MPN/100 g and only three results (5%) recorded as >230 *E. coli* MPN/100 g.

11.3 Overall geographical pattern of results

The geographical locations of Kyle of Tongue sample results are displayed in Figure 11.1. One sample had an unverified NGR and has been omitted from the geographical analysis. The majority of samples (61) were recorded to have been taken within 25 m of the RMP (NC 5932 5902). The RMP lies approximately 100 m south of the current reported oyster trestle area, where previous oyster production was centred (southeast corner of the production area). Four samples were reported to have been taken >100 m from the RMP; three in 2013 and one from 2009. Three of these plot a significant distance from the oyster farm. The sample taken in 2009 was the only sample recorded as having been taken from within the current oyster trestle area. Given the reported sampling locations, no conclusions can be drawn regarding any spatial aspects of *E. coli* contamination at the oyster trestles.

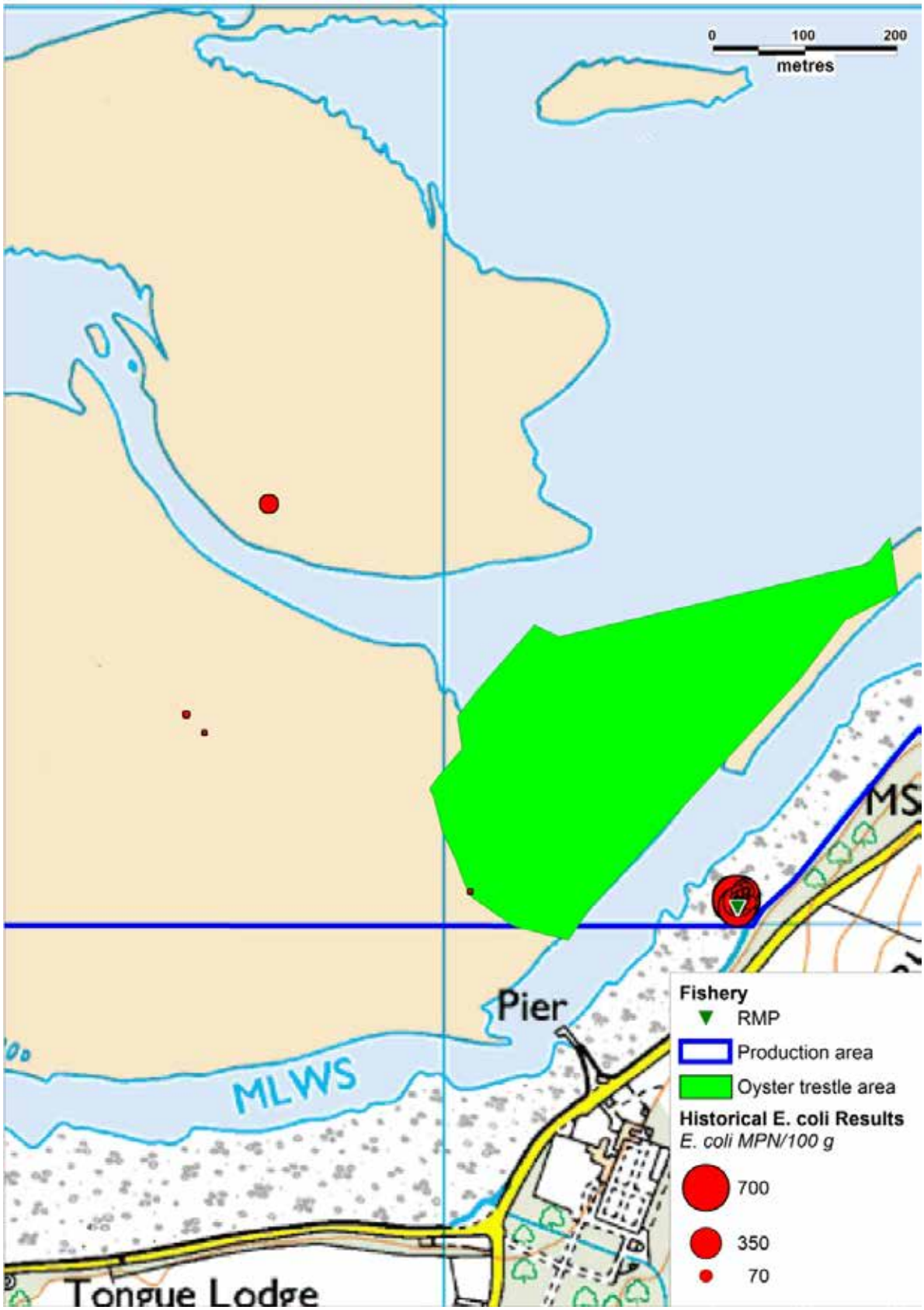


Figure 11.1 Map of reported sampling locations at Kyle of Tongue

11.4 Overall temporal pattern of results

A scatterplot of *E. coli* results against date for Kyle of Tongue 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.

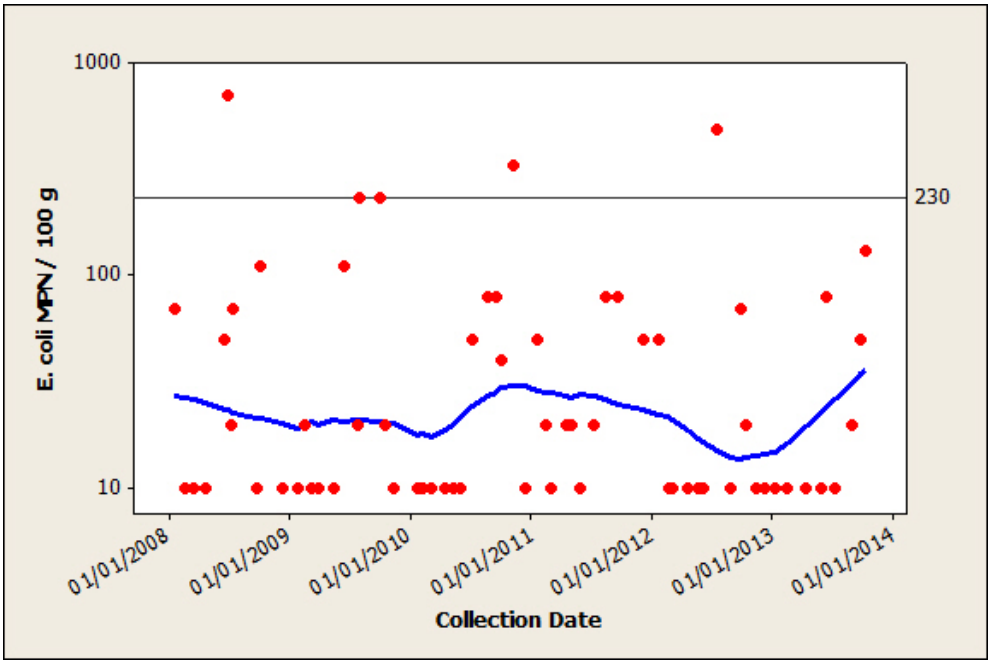


Figure 11.2 Scatterplot of *E. coli* results by collection date at Kyle of Tongue, fitted with a lowess line

Contamination levels have been generally consistent across the period shown except for late 2012 and early 2013, where a dip in the trend line is associated with several results of <20 *E. coli* MPN/100 g. This is followed by an increase at the end of the reported sampling period, owing to the absence of results <20 *E. coli* MPN/100 g at the end of the period.

11.5 Seasonal pattern of results

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns in human distribution. All of these can affect levels of microbial contamination, causing seasonal patterns in results. A scatterplot of *E. coli* results by month, overlaid by a lowess line to highlight trends is displayed in Figure 11.3. Jittering was applied at 0.02 (x-axis) and 0.001 (y-axis) respectively.

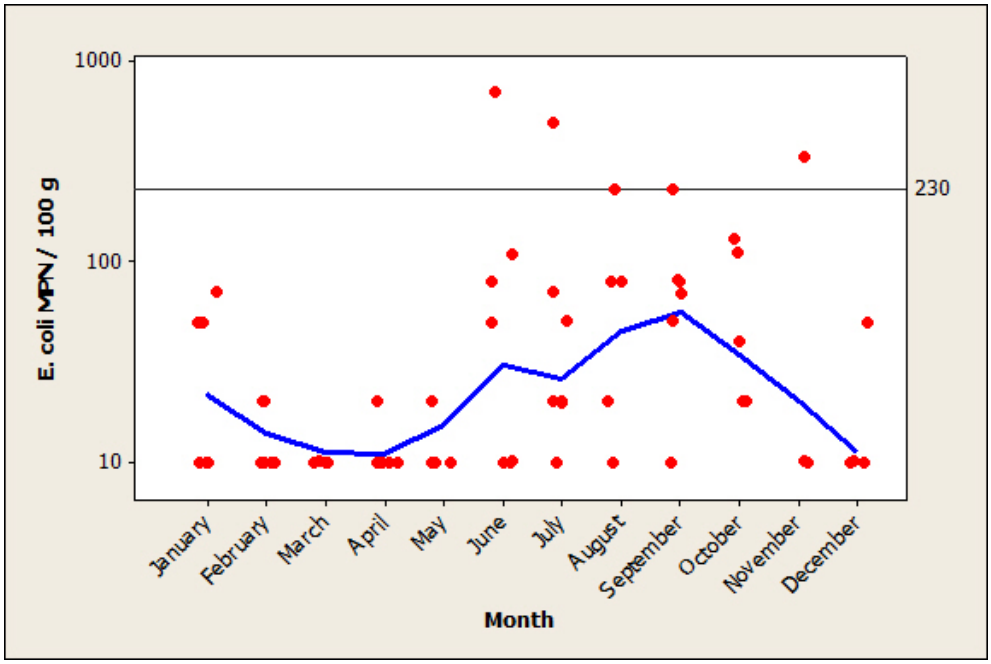


Figure 11.3 Scatterplot of *E. coli* results by month at Kyle of Tongue, fitted with a lowess line

The trend line peaks in September, although results ≥230 *E. coli* MPN/100 g occurred from June to November. Results between February and May were consistently low.

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 is presented in Figure 11.4.

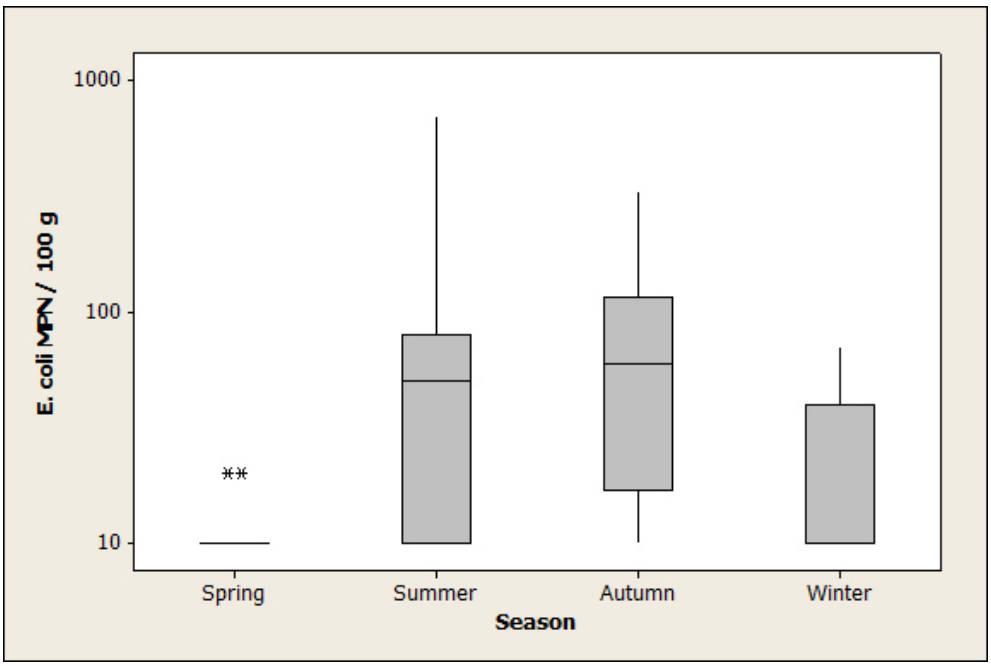


Figure 11.4 Boxplot of *E. coli* results by season at Kyle of Tongue

A very highly significant difference was found between *E. coli* results by season (one-way ANOVA, $p < 0.001$, Appendix 4), with results in summer and autumn significantly higher than those 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 at Harrish Quidnich approximately 5 km SW of the Kyle of Tongue site. Rainfall data was purchased from the Meteorological Office for the period of 01/01/07 - 31/12/2012 (total daily rainfall in mm). Data was extracted from this for all sample results at Kyle of Tongue 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 is displayed in Figure 11.5. Jittering was applied to results at 0.02 (x-axis) and 0.001 (y-axis) respectively.

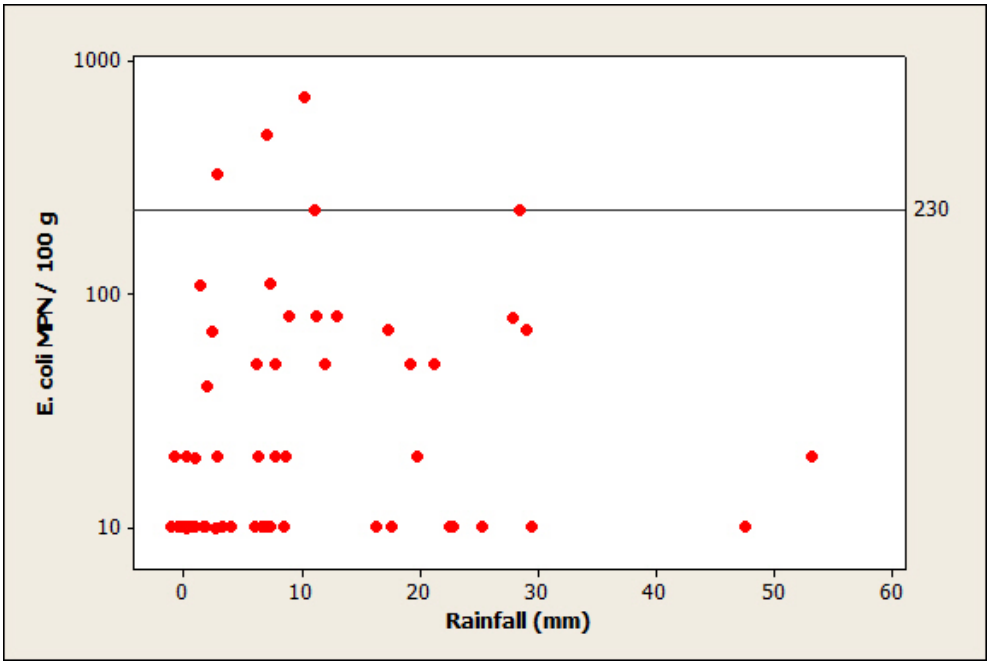


Figure 11.5 Scatterplot of *E. coli* results against rainfall in the previous two days at Kyle of Tongue

A significant correlation was found between *E. coli* results and the previous two day rainfall (Spearman's rank correlation r = 0.303, p = 0.023), with the highest results generally taken at rainfall levels >2 mm. However, results >230 *E. coli* MPN/100 g did not occur after rainfall exceeding 10 mm over 2 days.

Seven-day rainfall

The effects of heavy rainfall may take differing amounts of time to be reflected in shellfish sample results in different system, the relationship between rainfall in the previous seven days and sample results was investigated in an identical manner to the above. A scatterplot of *E. coli* results against total rainfall recorded for the seven days prior to sampling at Kyle of Tongue is shown in Figure 11.6. Jittering was applied at 0.002 (x-axis) and 0.001 (y-axis) respectively.

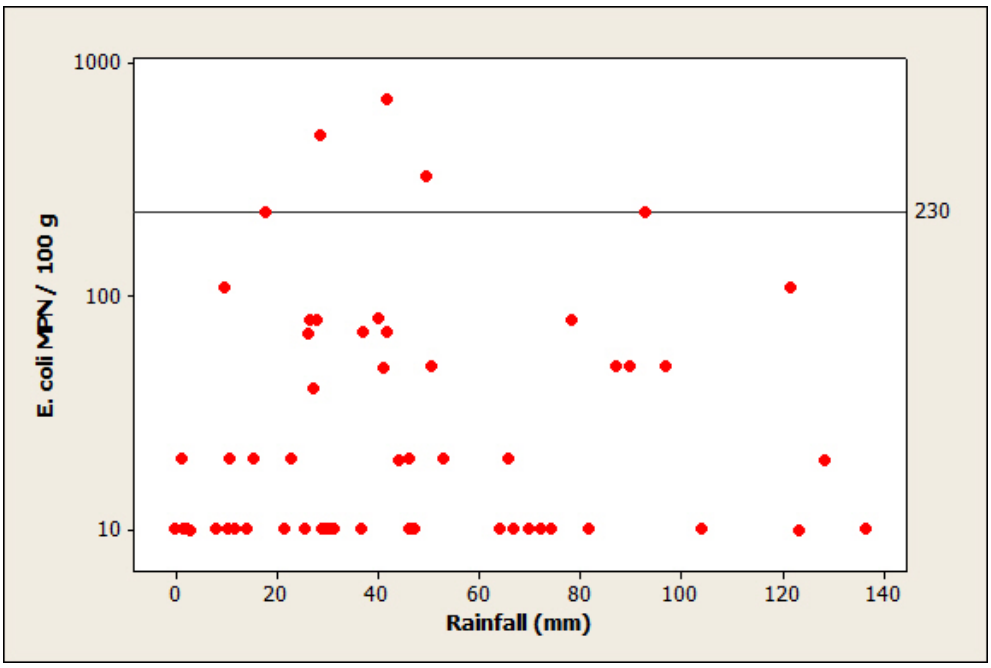


Figure 11.6 Scatterplot of E. coli results against rainfall in the previous seven days at Kyle of Tongue

No significant correlation was found between *E. coli* results and the previous seven day rainfall (Spearman's rank correlation r = 0.146, p = 0.281.

11.6.2 Analysis of results by tidal cycle

Spring/neap tidal cycle

Spring tides are large tides that occur fortnightly and are influenced by the state of the lunar cycle. They reach above the mean high water mark and therefore increase circulation and particle transport distances from potential contamination sources on the shoreline. The largest (spring) tides occur approximately two days after the full/new moon, at about 45^{o} on the polar plot. The tides then decrease to the smallest (neap) tides, at about 225^{o}, before increasing back to spring tides. A polar plot of

common mussel *E. coli* results against the lunar cycle is presented in Figure 11.7. It should be noted that local meteorological conditions such as wind strength and direction can influence height of tides and this is not taken into account.

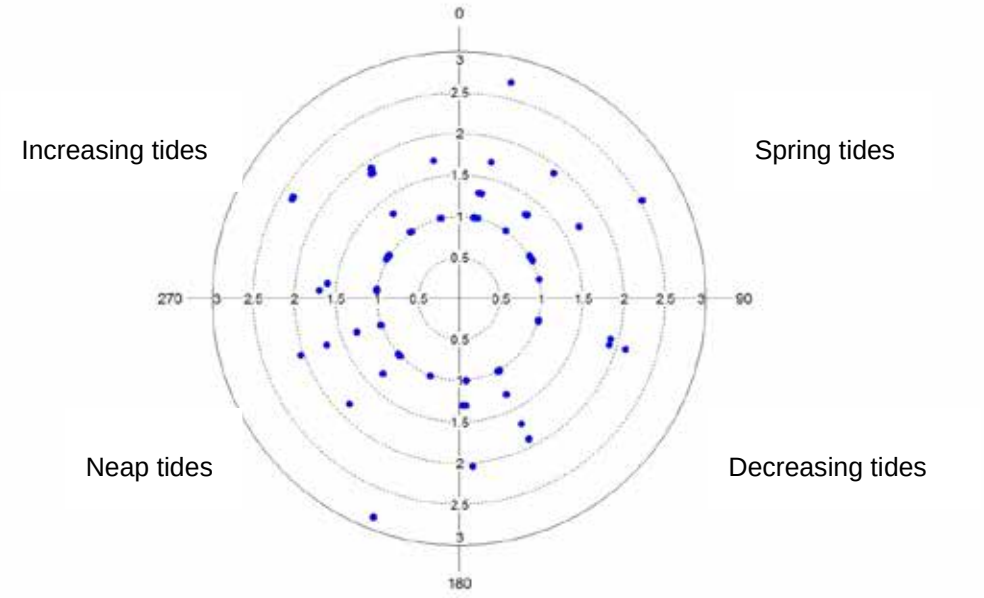


Figure 11.7 Polar plots of log10 E. coli results on the spring/neap tidal cycle at Kyle of Tongue

No significant correlation was found between $\log_{10}$ *E. coli* results and the spring/neap tidal cycle (circular-linear correlation r = 0.078, p = 0.686).

High/low tidal cycle

Tidal state (high/low tide) changes the direction and strength of water flow around production areas. Depending on the location of contamination sources, the state of tide 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, well within the time span of a single ebb or flood tide. Figure 11.8 presents a polar plot of *E. coli* results against the high/low tidal cycle. High water is located at 0^o on the polar plot and low water at 180^o.

High and low water data from Portnancon was extracted from POLTIPS-3 in October 2013. This site was the closest to the production area (approximately 14 km northwest) in the adjacent loch and it is assumed that tidal state will be very similar between sites.

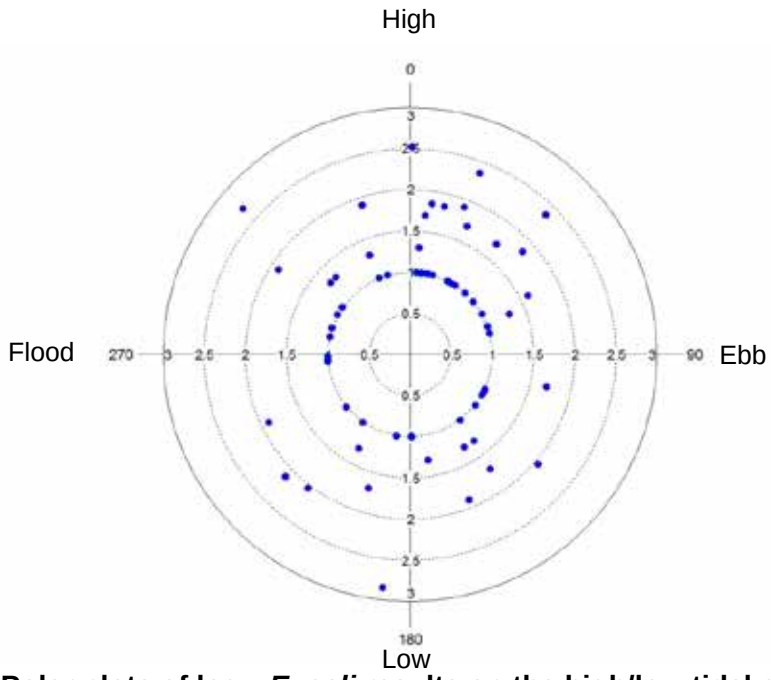


Figure 11.8 Polar plots of log_{10} *E. coli* results on the high/low tidal cycle at Kyle of Tongue

No significant correlation was found between log_{10} *E. coli* results and the high/low tidal cycle (circular-linear correlation r = 0.032, p = 0.94). Interestingly, despite the intertidal nature of the fishery samples were taken across a wide range of tidal states, including a significant number at and just after high 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. Figure 11.9 presents *E. coli* results against water temperature. Water temperature was recorded for 43/65 samples. Jittering of results was applied at 0.02 (x-axis) and 0.001 (y-axis) respectively.

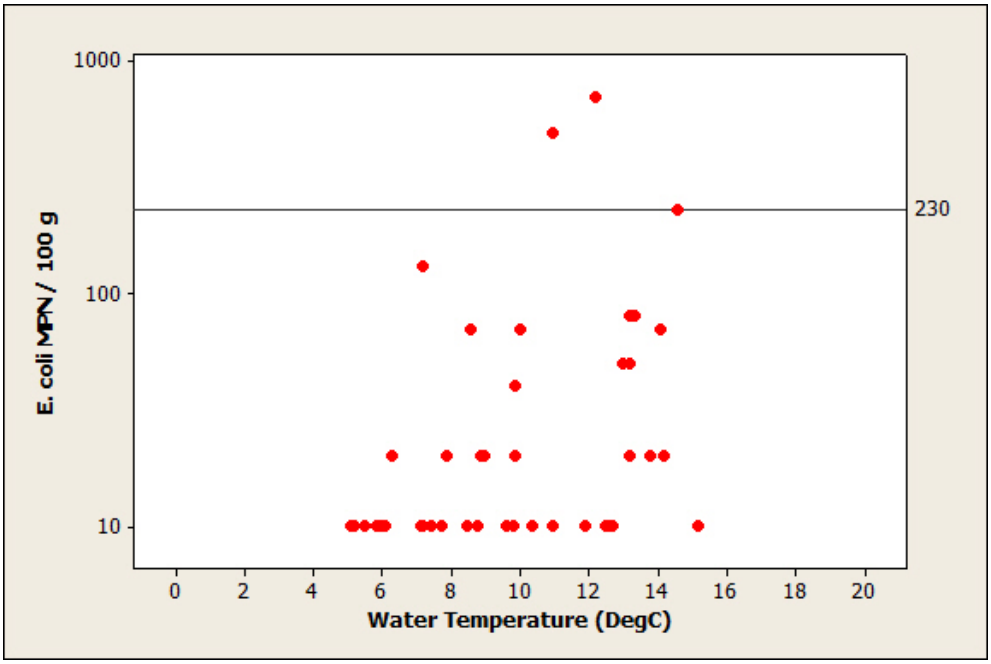


Figure 11.9 Scatterplot of *E. coli* results against water temperature at Kyle of Tongue

A significant correlation was found between *E. coli* results and water temperature (Spearman's rank correlation r = 0.466, p = 0.002). The highest results were taken at water temperatures >10^{o}C.

11.6.4 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence and hence freshwater borne contamination at a site. A scatterplot of *E. coli* results against salinity is shown in Figure 11.10. Salinity was recorded for 44/65 samples. Jittering was applied to results at 0.02 (x-axis) and 0.001 (y-axis) respectively.

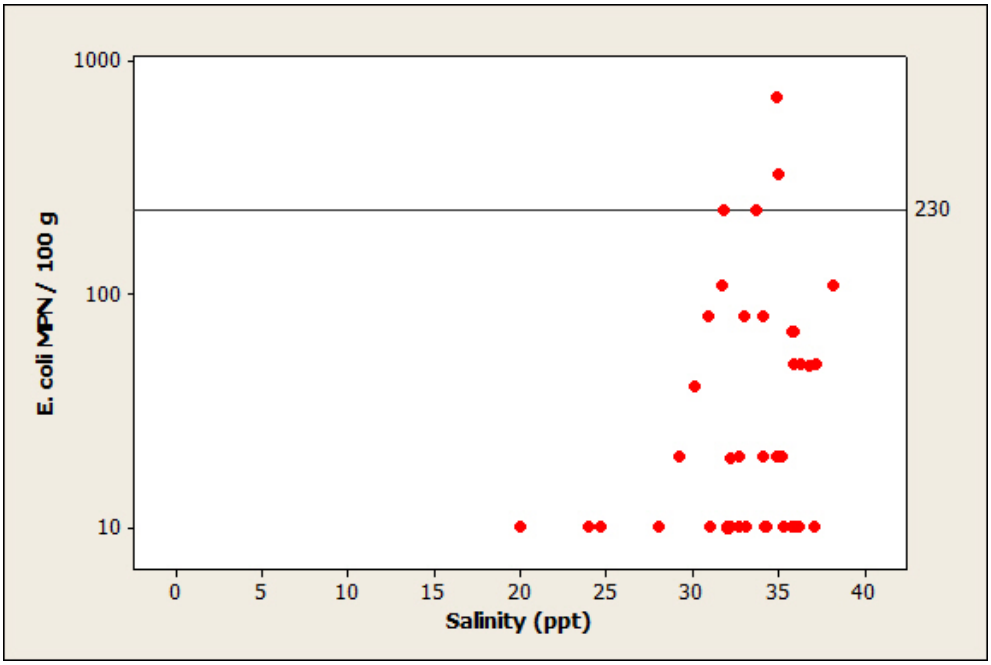


Figure 11.10 Scatterplot of *E. coli* results against salinity at Kyle of Tongue

No significant correlation was found between *E. coli* results and salinity (Spearman's rank correlation r = 0.244, p = 0.111).

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

In the results from Kyle of Tongue, three Pacific oyster samples had results >230 *E. coli* MPN/ 100 g and are listed below in Table 11.2.

Table 11.2 Historic Kyle of Tongue *E. coli* sampling results over 230 *E. coli* MPN/100g

Collection Date	*E. coli* (MPN/ 100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (^{o}C)	Salinity (ppt)	Tidal State (high/low)	Tidal state (spring/neap)
26/06/2008	700	NC 5932 5903	10.20	40.00	12.0	35	Low	Neap
08/11/2010	330	NC 5932 5903	2.50	49.20	-	35	High	Spring
18/07/2012	490	NC 5932 5902	6.40	28.10	11.0	-	Flood	Spring

-No data available

Results ranged between 330 and 700 *E. coli* MPN/100 g. They were reported in years 2008, 2010 and 2012, in June, July, and November. The reported sampling locations were at or within 10 m of the RMP (NC 5932 5902).

Rainfall over the previous two days varied between 2.50 and 10.20 mm and over the previous seven days between 28.10 and 49.20 mm. Water temperature was recorded for two results at 11 and 12^{o}C, with salinity recorded at 35 ppt for two samples. Tidal states varied.

11.8 Summary and conclusions

Overall, contamination levels were low over the period from 2007 to 2013 and only three samples had results >230 *E. coli* MPN/100 g. Sixty one of the 65 samples were recorded as having been taken within 25 m of the RMP, though the RMP currently lies approximately 100 m south of the oyster trestle area recorded during the survey. The highest sample results were recorded in June, July and November, with seasonality indicating an increase in results between summer and autumn. However, fewer samples have been taken in winter months.

A statistically significant correlation was found between sample results and previous two day rainfall but no correlation was found between results and previous seven day rainfall or between results and salinity.

A statistically significant correlation was found between results and water temperature, with highest results taken at seawater temperatures >10^{o}C.

No statistically significant correlation was found between results and high/low tidal cycle or spring/neap tidal cycle.

12. Designated Waters Data

The Kyle of Tongue production area is designated as Kyle of Tongue shellfish growing water (SGW), as shown in Figure 12.1. The area was designated in 2002 and covers the area bounded by lines drawn between NC 59770 62000 and NC 621066200 and between NC 57022 59000 and NC 59323 59000 extending to MHWS. This coincides with the classified production area boundary. The boundary of the designated waters will remain the same following the repeal of the Shellfish Waters Directive (2006/113/EC) in December 2013. There are no designated bathing waters in the area.

Since 2007, SEPA has used the FSAS *E. coli* data for assessing compliance with the microbiological guideline standard of the Directive. As this data has been analysed in Section 11, no separate assessment will be undertaken with respect to SGW compliance.

The SGW site report states that all freshwater inputs to the Kyle of Tongue are classified by SEPA as being of at least good quality. The impact from diffuse pollution sources is expected to be low with the main source of runoff from non-intensive hill farming. The waters have consistently passed all imperative and guideline standards since 2003: this includes the guideline standard for faecal coliforms.

13. Bathymetry and Hydrodynamics

13.1 Introduction

13.1.1 The Study Area

The Kyle of Tongue is situated on the northwest tip of Scotland and lies to the east of Cape Wrath. It is not a true sea loch unlike the neighbouring Loch Eriboll which lies 13 km to the west. It has a sand and mud composition and contains a narrow bar-encumbered channel running from north to south. However, together with Loch Eriboll, it is unique amongst Scottish loch and embayment systems in that it is exposed to the north. The main township of Tongue is situated along the eastern shore but housing is also sparsely dotted around the western shoreline centring around the crofting villages of Midtown, Skinnet and Talmine to the north of the study area. There is a road causeway across the middle of the Kyle stretching from Achuvoldrach on the western shore to Tongue on the eastern shore. The study area is shown in Figure 13.1.

Coordinates for the middle of Kyle of Tongue:

58° 29.74’ N 004° 26.08’ W

NC 58196 58958

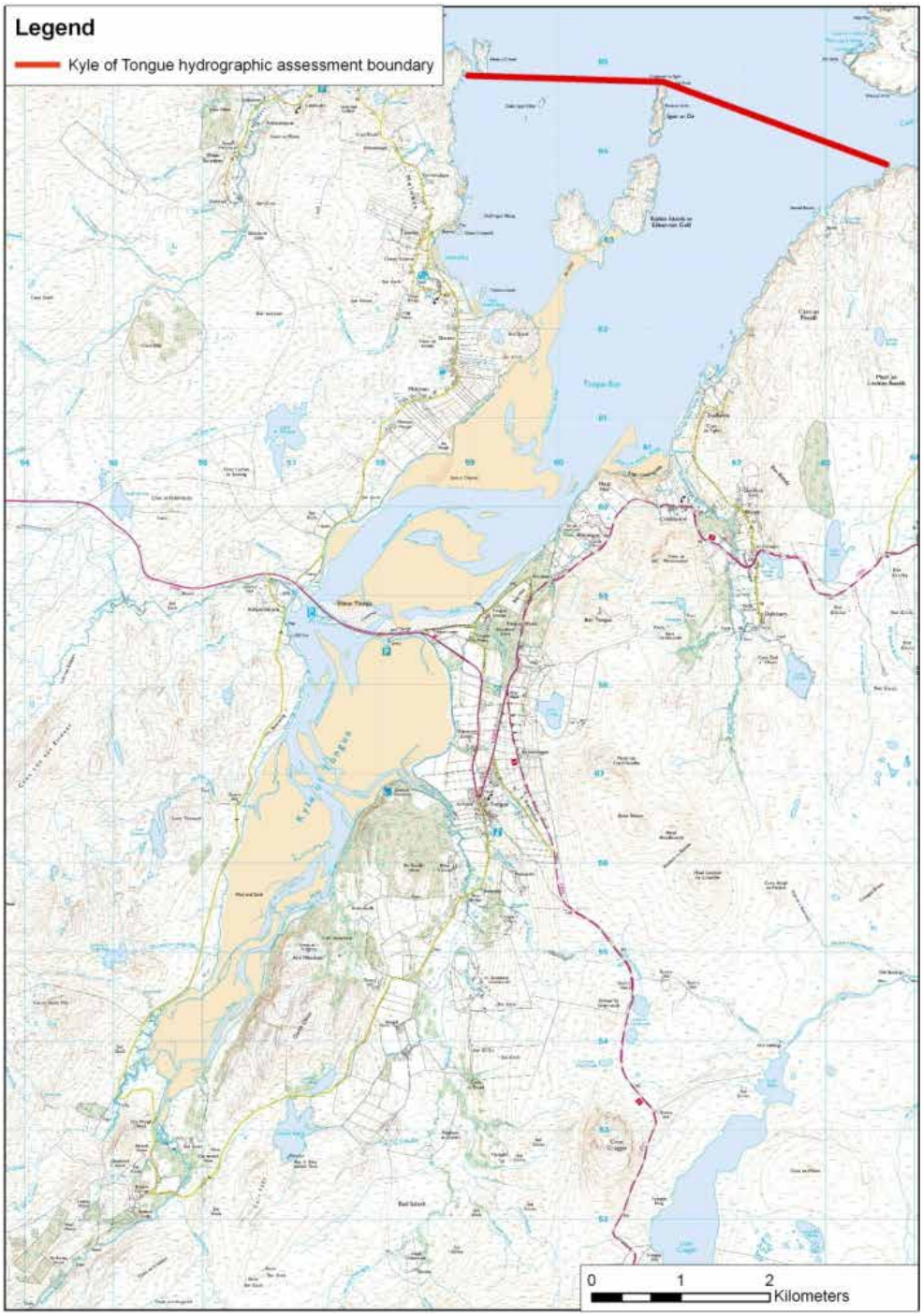
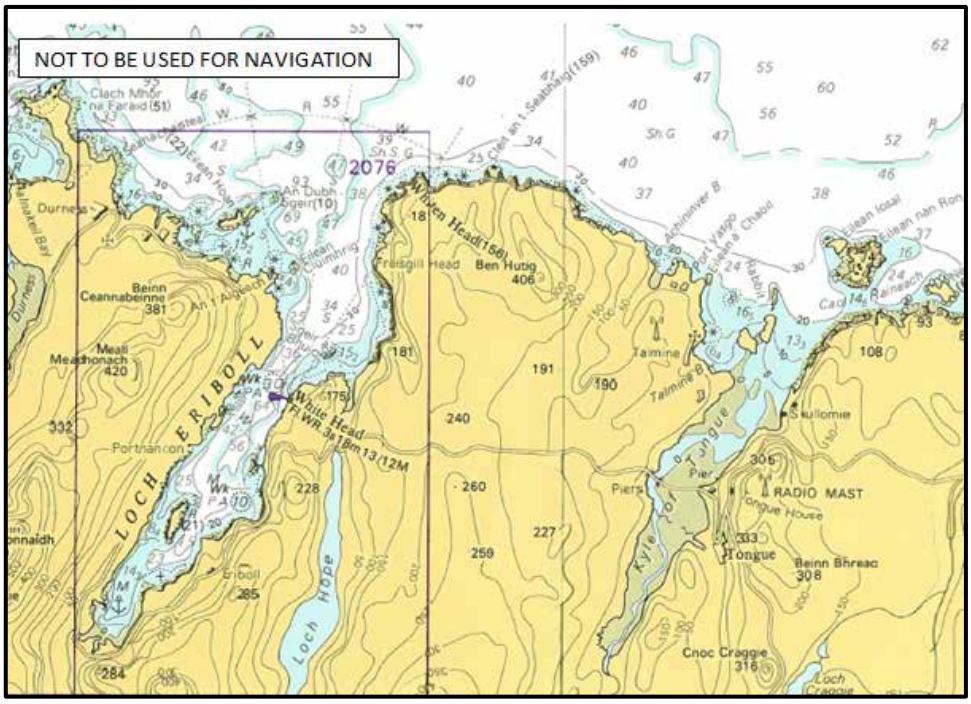


Figure 13.1 Extent of hydrographic study area

13.2 Bathymetry and Hydrodynamics

13.2.1 Bathymetry



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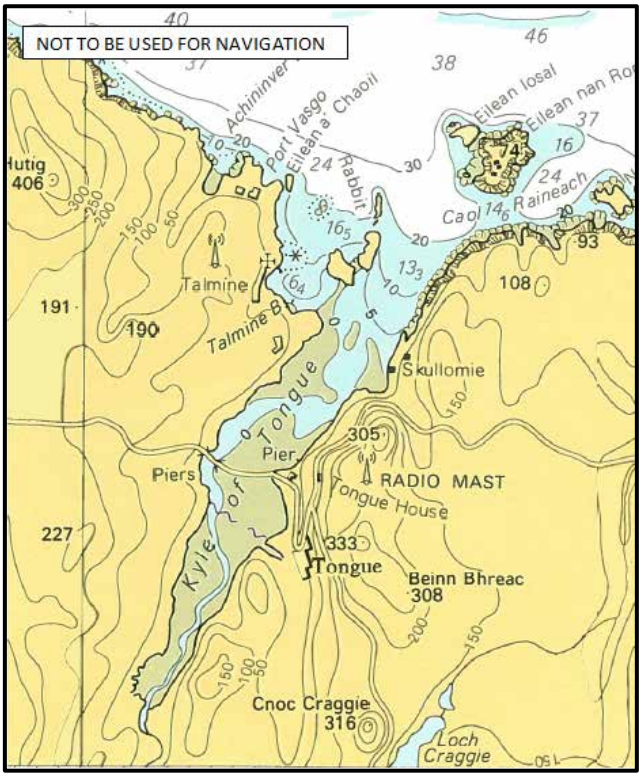

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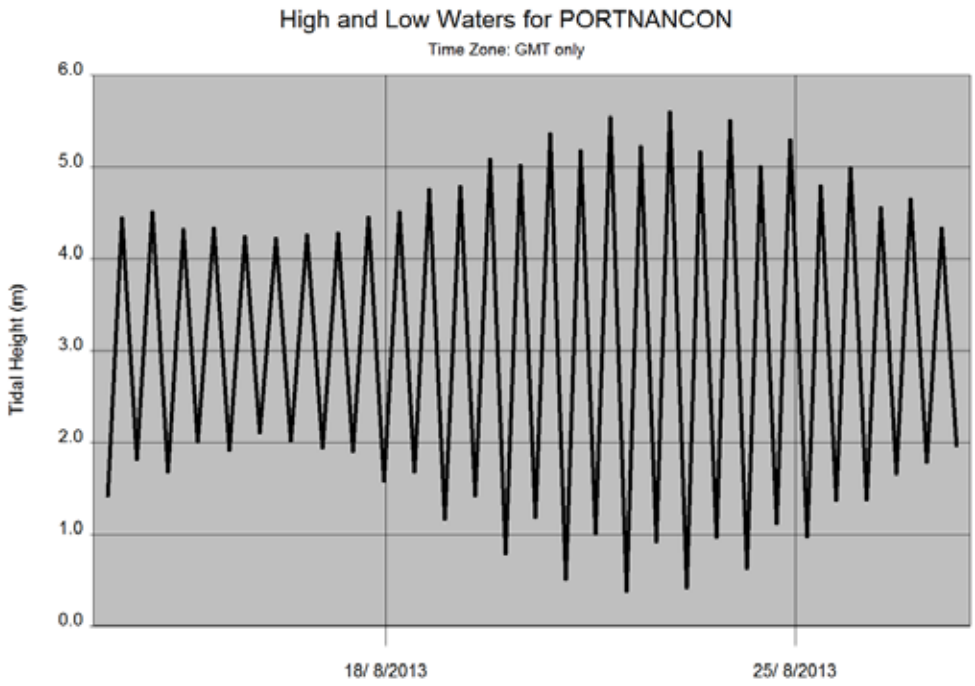
Figure 13.2 Admiralty chart (1954) extract for Kyle of Tongue

Figure 13.3 shows the bathymetry of Kyle of Tongue. The outer part of the Kyle of Tongue is approximately 3.6 km in length with a width of 1.7 km. However, the Kyle length in total is around 11 km, narrowing considerably shoreward. In contrast to Loch Eriboll, the bathymetry is relatively complex, being composed of shallow channels plus large intertidal sand flats, the morphology of which changes continually and therefore absolute measurements of depth are difficult to obtain. However, Admiralty Chart 1954 states that the maximum depth is 16 m at the entrance to the northwest. At the entrance, three islands named the Rabbit Islands essentially divide the mouth in two with a small bay to the west and the longer Kyle to the east. There is likely to be rather limited exchange between these two connected bodies of water.

13.2.2 Tides

The Kyle of Tongue has a typical semi-diurnal tidal characteristic though this is likely to be modified in the shallow waters of the embayment due to frictional effects. Data on tidal information is given from charted information. The nearest location for tidal predictions is Portnancon situated in the middle of Loch Eriboll, 13 km to the west of Kyle of Tongue [http://easytide.ukho.gov.uk]. Consequently, there may be some local difference with respect to range and phase of the tide.

Standard tidal data for Portnancon are given below and the spring/neap cycle of tidal height around the time of the survey (20 - 21 August 2013) is shown in Figure 2.2:



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

Figure 13.3 Two week tidal curve for Portnancon, Loch Eriboll.

Tidal Heights for Portnancon (from Admiralty Chart 1954):

Mean High Water Springs = 5.2 m
Mean Low Water Springs = 0.9 m
Mean High Water Neaps = 4.0 m
Mean Low Water Neaps = 2.2 m

Tidal Ranges:

Mean Spring Range = 4.3 m
Mean Neap Range = 1.8 m

13.2.3 Tidal Streams and Currents

There are no tidal diamonds for this area. Enhancement of tidal streams caused by spits and channels are likely to be significant in the Kyle of Tongue due to its rather complex bathymetry. However, there may be some localised effects around the Rabbit Islands, the large archipelago towards the mouth of the Kyle and also Eilean nan Ron to the northeast of the entrance.

There are no current meter data within the SEPA database available for this site that can be used to assess the flow in this area.

Dispersion is an important property of a water body with respect to redistribution of contaminants over time. There are no measurements or published data relating to dispersion in the Kyle of Tongue. Without such data it is difficult to judge what the dispersive environment might be like, but the occurrence of small promontories, shallow banks and sand spits may enhance dispersion.

Dispersion of surface contaminants may be enhanced by wave energy within the study area. Sources of wave energy are from both short period waves that are created within the lee of the Kyle of Tongue and from swell conditions that have a much larger period originating in the North Atlantic.

For Loch Eriboll situated 13 km to the west of the Kyle of Tongue, the longest fetch lengths occur in the north east/south west direction and the biggest wind generated waves are produced from these wind directions. For Eriboll, and presumably Kyle of Tongue, the area most affected by winds originating from the northern quarter is the wide outer part of the loch which will result in powerful wave action in shallow water (Moss, 1986). It may be appropriate to compare these areas due to their close proximity and similar aspect.

13.2.4 River/Freshwater Inflow

There are numerous fresh water inflows in the area. Towards the north on the east shore, Strathtongue Burn flows into Coldbackie Bay. Tongue Burn flows through the settlement of Tongue and reaches the main body of the Kyle although this is dependent on the season and flow rate. To the south of Tongue, Rhian Burn is one

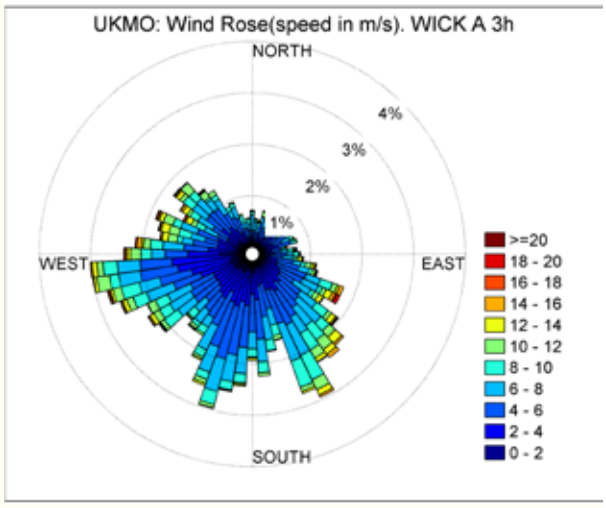
of the main sources of freshwater input in the lower reaches of the Kyle along with Kinloch River to the extreme south. On the western shore of the site, numerous smaller inputs can be found through An Garbh-Allt, Allt Loch na h-Airigh Bige, Allt Loch Fhionnaich and Alltan na h-Atha. There are other unnamed rivers on the OS chart which may or may not flow depending on the season.

There are no formal estimates of runoff for Kyle of Tongue. The annual precipitation at nearby Loch Eriboll is approximately 1500 mm (Edwards & Sharples, 1986) but the run-off for Kyle of Tongue is not known. However, there are a number of significant rivers feeding into the Kyle and so we anticipate that fresh water influence is important to circulation and stratification.

13.2.5 Meteorology

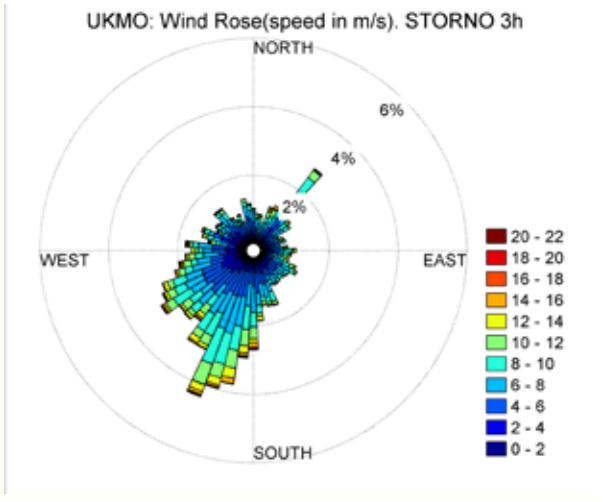
The formal meteorology assessment for the area must be used with caution. Rainfall data were taken from Achfary which is situated roughly 34 km southwest of the assessment area and spanned the time frame from January 2007 to December 2012.

Data on wind is available from two stations, Wick Airport which is located 75 km east of the production area and Stornoway airport which is approximately 120 km to the south west. Whilst Wick is physically closer we opt to use wind statistics from Stornoway. This is based on a comparison of the wind roses for each airport (derived from data 2011-2013) with output from the Weather Research and Forecasting Model [http://www.wrf-model.org] for Kyle of Tongue. This is shown in figure 13.4 below. In particular, note the dominance of wind from the south west.



(a)

(b)



(c)

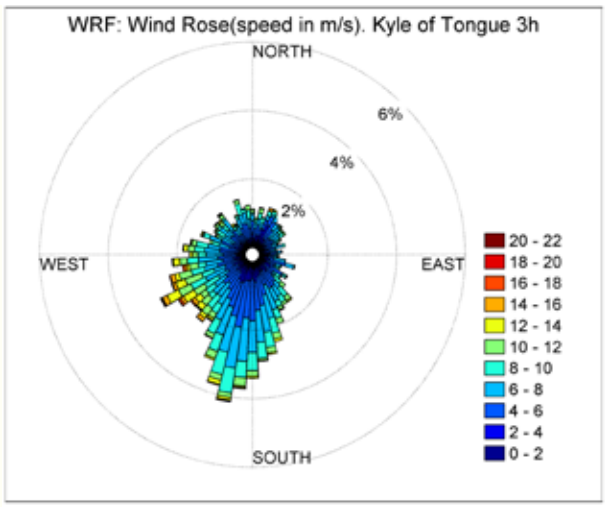


Figure 13.4 Wind roses for (a) Wick, (b) Stornoway and (c) Kyle of Tongue derived from two years of observations (Wick and Stornoway) or WRF model output (Kyle of Tongue).

The year with the highest rainfall was 2007 and the least rain fell in 2010. Unusually in 2007 and 2008, 70 mm/d of rainfall was exceeded but generally high rainfall values (>30 mm/d) were seen in all years. The highest daily rainfall values occurred throughout the autumn and winter seasons where rainfall increased from September onward. The highest recorded rainfall was in November and January. Rainfall was lower in the months April to August. There was rainfall of >30 mm/d in all months with the exception of June. For the duration of the data set, daily rainfall of below 1 mm occurred 40% of the time and daily rainfall of above 10 mm occurred 18% of the time.

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

Data about wind conditions is from Stornoway. Due to the distance between the two areas, the wind rose statistics should be used with caution, although the comparison of wind data shown in Figure 13.4 shows that the sites have long term similarities.

The data from Stornoway shows that, overall, westerly and southerly winds were stronger than northerly or easterly winds. There is a predominant south-westerly airflow year round for the area. Our assessment is that winds in the southwest quadrant will dominate. It is highly likely that the local wind direction in the production area will be influenced by the morphology of the surrounding high ground.

13.2.6 Model Assessment

Due to the paucity of data for this location and the unconstrained nature of the study area, it was not considered appropriate to set up a box model run for the assessment area.

13.3 Hydrographic Assessment

13.3.1 Surface Flow

The site and the rainfall data indicate that there is likely to be a rather moderate freshwater discharge into the surface waters of the Kyle relative to its depth. Although the absolute value of discharge is unknown it is expected that it would have moderate seasonal variation.

The area is relatively long but the composition of sand flats and water channels will dictate that there is likely to be significant variation in salinity and stratification of the surface properties along the axis of the Kyle. It is likely to be more saline and well mixed at the mouth of the area.

Surface flows would be enhanced/retarded by winds blowing out of/into the loch, particularly from the dominating south-westerly direction, and also enhance the mixing of the waters through the full depth.

There are no direct measurements of tidal or residual flow in the area. However, it is likely that the long term flow will most likely have an estuarine nature with the tidal flow running approximately SW on the flood and NE on the ebb and an overlying freshwater flow to the NE. Consequently, over the course of a tidal cycle there is likely to be a surface residual flow to seaward.

The dispersive characteristics of the site are unknown but there will be enhanced dispersion as the flow encounters sand spits and islands along the path of the flow and in periods of strong wind.

13.3.2 Exchange Properties

It is likely that the tidal flow dominates the exchange properties of the Kyle of Tongue. Compared to locations with similar properties in terms of size and bathymetry, e.g. Loch Ryan, one might expect the flushing time to be around 5-7 days. However, the prevailing winds from the south west quadrant may enhance surface flushing rates which may be further enhanced during periods of high freshwater discharge.

It is expected that Kyle of Tongue would be a moderately-well flushed system throughout most of the year with surface contaminants being effectively dispersed in the residual flow.

There are no data available from current meters for Kyle of Tongue and there is a paucity of any measured hydrographic data. Therefore the confidence level of this assessment is LOW.

14. Shoreline Survey Overview

The shoreline survey at the Kyle of Tongue was conducted on the 20th and 21st August 2013. No rain was recorded in the 48 hrs prior to the survey, with rain only recorded on the evening of the first survey day. Temperature varied between 14 and 15°C, with winds dropping from 20 km/h to 6 km/h in SW and S directions.

The Kyle of Tongue fishery consists of a large trestle based Pacific oyster production. The site is currently owned by Ms Despres, who has been the named harvester for approximately a year, taking over from Mrs Mackay who previously ran a much smaller Pacific oyster fishery, consisting of a few trestles on the southeast shoreline.

At the time of the survey an estimated 15,000 trestles were situated offshore on sandbanks southeast of the production area. In total, four rows of trestles were stocked with mature oysters, which had been left over from the original fishery. Approximately 26-30 million juvenile oysters from Morecombe had been stocked on site in June 2013. These were on trestles furthest from shore, to enable fast growing rates. They were in densities of roughly 2000 oysters per bag, which Ms Despres said was reduced to 150 oysters per bag once they reached 1-2 years. A large number of trestles remained empty to allow for redistribution of juveniles. It is expected that oysters will take 3 years to mature.

Ms Despres stated that she planned to increase stock to 40 million oysters (including both juvenile and mature oysters). Eight members of staff were working on the farm with two tractors at the time of the survey. Two Pacific oyster samples taken at the southwest extent of the fishery, both returned results of <20 *E. coli* MPN/100 g. Seawater samples taken at the southwest, northwest and northern extents of the fishery returned results of 0 *E. coli* cfu/100 ml.

The majority of the human population was found in Midtown (northwest) and Tongue (east), with a small number of dwellings also observed outside these settlements. Tongue Lodge Youth Hostel located on the south shore was the only tourist accommodation observed. A cemetery was noted to the southwest, close to the bridge. A seawater sample taken adjacent to the Cemetery returned a result of 36 *E. coli* cfu/100 g. Three pipes were observed during the survey, though two were dry at the time of the survey. The third pipe was small and metal, located by the pier below Tongue House (southeast) and returned a freshwater sample result of 600000 *E. coli* cfu/100 ml.

One pier next to Tongue House (southeast) and a single mooring site (western shore) were observed, but no boats were present at the time of the survey.

The land surrounding the Kyle of Tongue is a mixture of rough grazing and crofting land, with one farm and most of the agricultural land (arable and crop fields) noted

along the western shore. Thirty-five sheep were observed in total, all along the western shore, with access to the shoreline. Areas of woodland and forestry were observed along the eastern shore.

Five watercourses were sampled during the survey; three on the eastern shore and two on the western shore. Results for samples taken from these ranged from 320 *E. coli* cfu/100 ml (an unnamed watercourse on the eastern shoreline) and 1340 *E. coli* cfu/100 ml (Achuvoldrach Burn on the southwestern shoreline). Three stagnant land drainage areas were also noted along the western shore.

Birds were the only wildlife observed during the survey, with species including gulls, geese, oystercatchers, and herons.

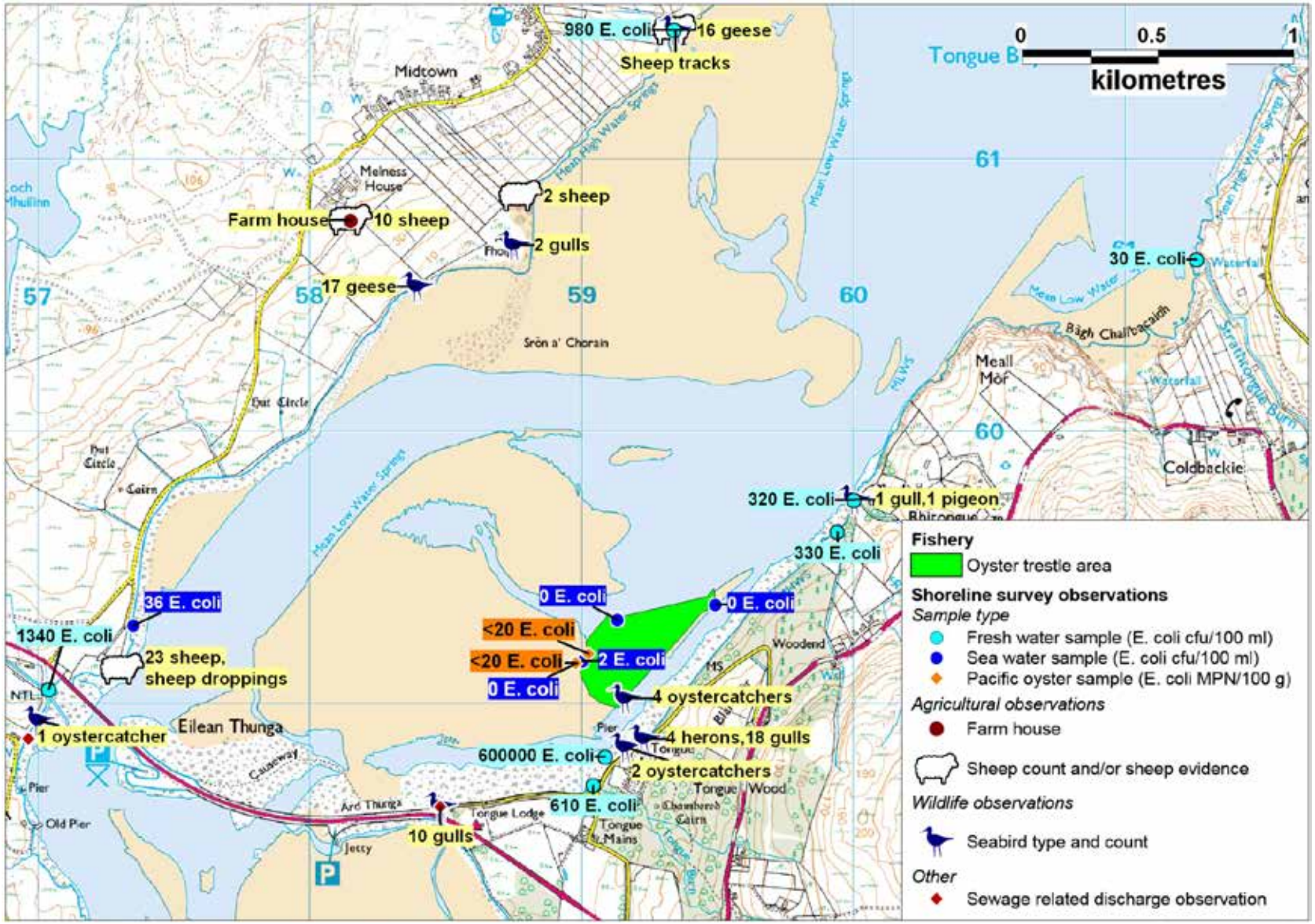


Figure 14.1 Principal shoreline survey findings for Kyle Of Tongue

15. Overall Assessment

Human sewage impacts

Although the overall permanent population of the area is relatively low, in summer there is likely to be a significant influx of visitors relative to the total population. The nearest community septic tank, at Coldbackie, lies approximately 2 km northeast of the northern end of the oyster farm. Little was known about the size or discharge location of this septic tank at the time of drafting this report. A further public septic tank lies to the northwest, at Talmine. Despite the presence of community sewage systems, there were a significant number of private septic tanks.

An active private septic tank outfall was found approximately 200 m southeast of the southern end of the oyster farm. Discharge from this tank would be most likely to affect the southeastern corner of the farm.

Agricultural impacts

The main agricultural activity in the area is croft-based rearing of livestock, predominantly sheep. Sheep were seen along the northwest shoreline, along the crofting townships of Midtown and Talmine. Although no livestock were seen along the eastern shore, review of other sources showed that sheep are also kept on fields around Tongue, Rhitongue and Coldbackie. Impacts from animals kept in these areas are most likely to be transported via watercourses and rainfall runoff from areas directly adjacent to the shoreline. There is likely to be a greater impact during summer, when there are more animals present.

Livestock are also kept on crofts along the northwest shore. It is not clear whether contamination arising from these would directly impact at the oyster farm, though it may contribute to background levels of contamination in the Tongue Bay.

Wildlife impacts

There are dense concentrations of seabirds located at the head of Kyle of Tongue at Rabbit Island and further offshore on Eilean nan Ron. Birds include both resident and migratory species. These dense concentrations of bird colonies are located >4 km from the current fishery at the Kyle of Tongue. Any impacts at the fishery would be greatest from birds feeding or roosting in the vicinity of the trestles. However, it is likely that seabirds contribute to background levels of faecal contamination throughout the area particularly during summer.

Seasonal variation

There is likely to be significant seasonal variation in the numbers of people, livestock and seabirds present in the area, with the highest numbers of all of these occurring in summer. Seasonal variation was seen in historical *E. coli* monitoring results, with

contamination levels reaching a peak in September after a trough from February to May. Highly statistically significant variation was seen in results by season, with results in summer and autumn higher than in spring and winter.

Watercourses

Four watercourses enter into the Kyle within 1 km from the current location of the oyster fishery. Contamination from Tongue Burn is most likely to affect the southeast extent of the fishery, whilst contamination from three unnamed watercourses is expected to mostly impact the northeast extent of the fishery. During or following periods of heavy rainfall, it is expected that loadings from these watercourses will be higher due to the presence of both human and wildlife sources in the catchment area.

A statistically significant correlation was found between *E. coli* results and rainfall during the two days prior to sampling. Highest results occurred after <10 mm rainfall over two days. No correlation was found between *E. coli* results and rainfall during the seven days prior to sampling. No significant correlation was found between *E. coli* results and salinity recorded on the day of sampling.

Movement of contaminants

Very little hydrographic information was available on the Kyle of Tongue and Tongue Bay as there were no direct measurements of tidal or residual flow in the area.

Long term flow will most likely be estuarine in nature with the tidal flow running approximately southwest on the flood and northeast on the ebb with an overlying freshwater flow to the northeast. Consequently, over the course of a tidal cycle there is likely to be a surface residual flow to seaward.

Dispersion of contaminants is likely to be enhanced as the flow encounters sand spits and islands along the path of the flow and in periods of strong wind.

Temporal and geographical patterns of sampling results

Overall, contamination levels were low over the period from 2007 to 2013 and only three samples had results >230 *E. coli* MPN/100 g. The trend over the time period was broadly level.

The large majority of samples were recorded as having been taken within 25 m of the RMP, which currently lies approximately 100 m south of the oyster trestle area recorded during the survey. Very few samples were taken from within the oyster farm area itself,, and therefore it was not possible to assess spatial variation in results across the fishery. Two oyster samples were taken during the shoreline survey, both along the southwestern edge of the oyster farm and only 60 m apart. Both returned results of <20 *E. coli* MPN/100 g. Seawater samples taken from other locations within the fishery returned similarly very low results of 0-2 *E. coli* cfu/100 ml, suggesting little detectable faecal contamination at the time of sampling.

A statistically significant correlation was found between results and water temperature, with highest results taken at seawater temperatures >10^{o}C. It was not possible to determine whether this was due to increased feeding rates or higher levels of contamination coinciding with periods of higher temperatures (i.e. summer).

Conclusions

Overall, the fishery is subject to low levels of faecal contamination. Point source sewage contamination to the fishery is contributed from a private property on the adjacent shoreline southeast of the oyster farm, and though community septic tanks discharge to watercourses further away from the oyster farm they may contribute to background levels of faecal contamination there particularly during summer when the human population in the area is likely to be higher. Diffuse pollution from livestock and wildlife sources is also present, and of these livestock are likely to have a more significant contribution due to their proximity to the oyster farm. Sheep kept on fields to the south and north of the oyster farm are likely to contribute to faecal contamination carried in watercourses draining the area. The highest estimated loading from these (based on observations at the time of shoreline survey) was from Tongue Burn, to the southeast of the oyster farm.

16. Recommendations

Production area

It is recommended that the production area boundaries be extended southward to include the full extent of the oyster farm. The northern boundary should be curtailed to exclude the mouth of Strathtongue Burn and also the more heavily crofted shoreline from Midtown to the northwest. The recommended production area boundaries are the area bounded by lines drawn between NC 5731 5909 and NC 5913 5888 and between NC 5879 6058 and NC 6021 6011 and extending to MHWS.

RMP

It is recommended that the RMP be relocated to the southeast extent of the oyster trestle area, where it will better reflect conditions at the farm and to reflect any contamination arising from the sewage discharge along the shore to the south.

Tolerance

The recommended sampling tolerance is 10 metres.

Depth of sampling

Not applicable due to intertidal nature of fishery

Frequency

Due to the seasonality of sources and observed seasonality in monitoring results, it is recommended that monthly sampling be continued.

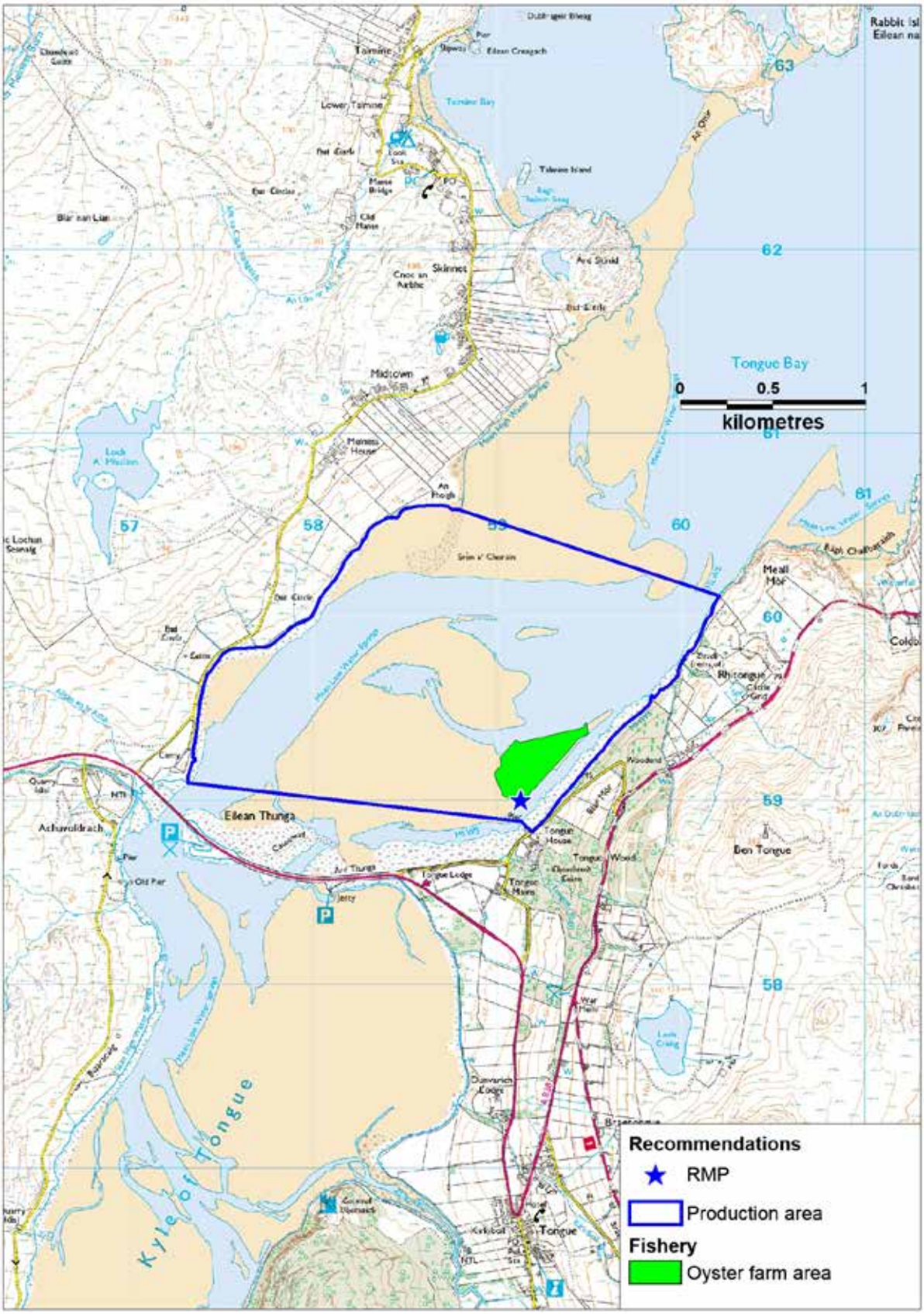


Figure 16.1 Map of recommendations at Kyle Of Tongue

17. References

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

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

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

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

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

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

Mitchell, I. P., Newton, S. F., Ratcliffe, N. & Dunn, T. E., 2004. *Seabird populations of Britain and Ireland: results of the Seabird 2000 census (1998-2002),* London: T & A D Poyser.

Moss, D., 1986. *Report on a sublittoral survey of Loch Eriboll (Sutherland). ,* Manchester: Marine Conservation Society.

Picture the UK, 2013. *Croit- Na-Mara.* [Online] Available at: http://www.picturetheuk.com/uk-tourism/places-to-stay/croit-na-mara-8620.html
[Accessed 13 11 2013].

Robinson, R. A., 2005. *BirdFacts: profiles of birds occuring in Britain & Ireland (BTO Research Report 407)..* [Online] Available at: www.bto.org/birdfacts
[Accessed 13 11 2013].

Royal Commission on the Ancient and Historical Monuments of Scotland (RCAHMS), 2013. *Tongue, Ferry Lookout.* [Online] Available at: http://canmore.rcahms.gov.uk/en/site/5337/details/tongue+ferry+look+out/
[Accessed 16 10 2013].

Sea Watch Foundation, 2007. *Cetaceans of Western Scotland.* [Online] Available at: http://seawatchfoundation.org.uk/wp-content/uploads/2012/07/WesternScotland.pdf
[Accessed 13 11 2013].

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

Undiscovered Scotland, 2013. *Talmine.* [Online] Available at: http://www.undiscoveredscotland.co.uk/tongue/talmine/index.html [Accessed 13 11 2013].

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1. General Information on Wildlife Impacts

Pinnipeds

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

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

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

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

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

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

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

Cetaceans

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

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

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

Birds

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

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

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

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

Deer

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

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

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

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

Other

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

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

References

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

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

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

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

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

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

2. Tables of Typical Faecal Bacteria Concentrations

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

Indicator organism	**Base-flow conditions**				**High-flow conditions**			
Treatment levels and specific types: Faecal coliforms	n^c	Geometric mean	Lower 95% CI	Upper 95% CI	n^c	Geometric mean	Lower 95% CI	Upper 95% CI
Untreated	252	$1.7 \times 10^{7*}$ (+)	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}		

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

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

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

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

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

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

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

Source: (Gauthier & Bedard, 1986)

References

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

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

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

3. Statistical Data

One-way ANOVA: logec versus season

```
Source  DF      SS     MS     F      P
season   3   4.713  1.571  8.75  0.000
Error   62  11.137  0.180
Total   65  15.850

S = 0.4238   R-Sq = 29.74%   R-Sq(adj) = 26.34%

                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev  --+---------+---------+---------+-------
1      16  1.0376  0.1028  (------*------)
2      20  1.6198  0.5670                    (-----*-----)
3      14  1.6850  0.5034                     (------*-------)
4      16  1.2215  0.3241        (------*------)
                          --+---------+---------+---------+-------
                          0.90      1.20      1.50      1.80

Pooled StDev = 0.4238

Grouping Information Using Tukey Method
season   N    Mean  Grouping
3       14  1.6850  A
2       20  1.6198  A
4       16  1.2215    B
1       16  1.0376    B
```

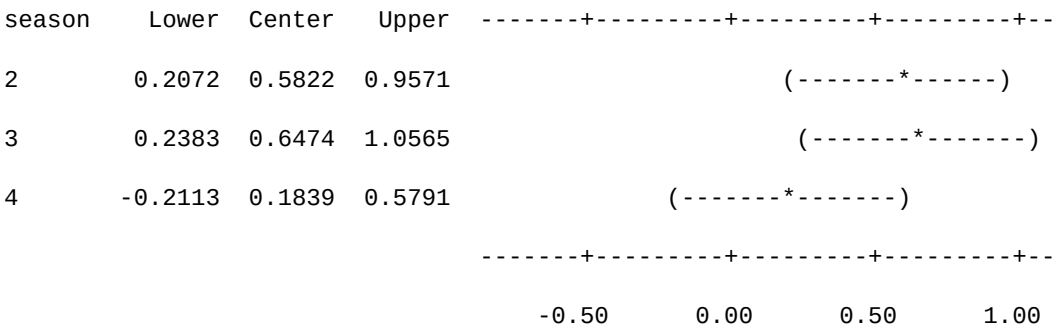
Means that do not share a letter are significantly different.

Tukey 95% Simultaneous Confidence Intervals

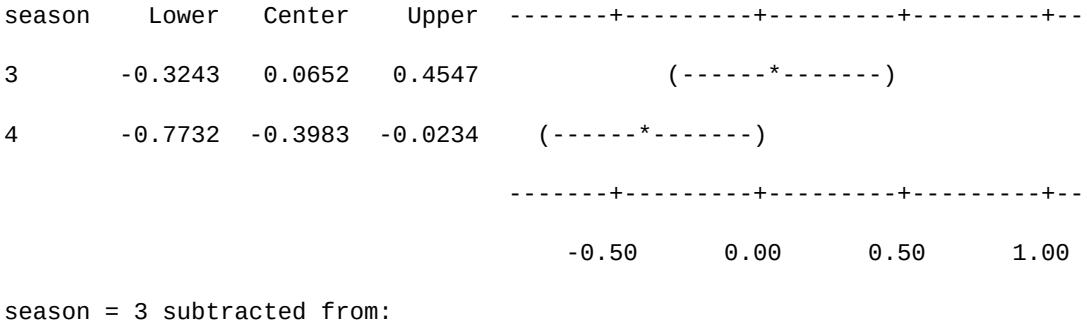
All Pairwise Comparisons among Levels of season

Individual confidence level = 98.95%

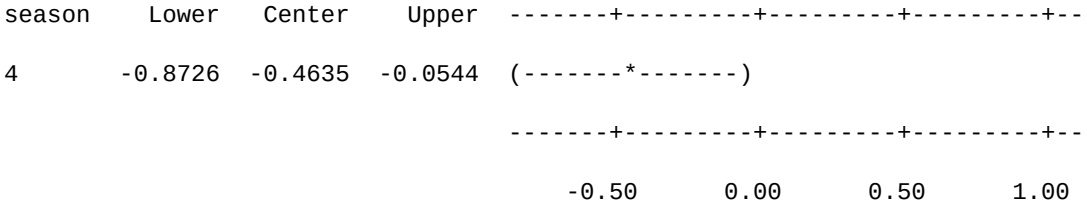
season = 1 subtracted from:



season = 2 subtracted from:



season = 3 subtracted from:



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

Document Number	B0067_Shoreline 0019
Revision	Issue 02
Date	10/10/2013

Revision History

Revision	Changes	Date
A	Issue for internal review	04/09/2013
01	First formal issue to CEFAS	25/09/2013
02	Revision addressing comments on Issue 01	10/10/2013

	Name & Position	Date
Author	Eilidh Cole, Colin Abernethy	28/08/2013
Checked	Andrea Veszelovszki, John Hausrath	10/09/2013
Approved	John Hausrath	10/10/2013

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

Shoreline Survey Report

Production area: Kyle of Tongue
Site name: Kyle of Tongue
SIN: HS-103-303-13
Species: Pacific Oysters (*Crassostrea gigas*)
Harvester: Ms. Charlotte Despres
Local Authority: Highland Council: Sutherland
Status: Existing area
Date Surveyed: 20th – 21th of August 2013
Surveyed by: Eilidh Cole, Colin Abernethy
Existing RMP: NC 5932 5902

Area Surveyed:
Three separate areas around the Kyle of Tongue were surveyed over two days: (1) The shoreline at the northwest of the bay near Midtown (from south of Skinnet to south of Midtown), (2) The shoreline at the southwest of the bay near the cemetery and Achuvoldrach, (3) The southeast shoreline from Tongue Lodge to just north of Rhitongue.

Weather:
No precipitation was experienced during the two survey days, however, there was rain overnight on Tuesday 20th August. There was no precipitation over the previous 48hr period.
Tuesday 20th August 2013 – Warm and dry, temperature around 14°C, SW wind around 20 km/h with stronger gusts. Cloud cover 70%.

Wednesday 21st August – Warm and dry but with wet ground due to overnight rainfall. Temperature around 15°C, very calm in the morning with wind speeds approximately 6 km/h in a southerly direction. Cloud cover 100% with fog in the morning. Both cloud and fog cleared by the afternoon. There was a heavy rain shower at the end of the day after the survey was completed.

Stakeholder engagement during the survey
Both the harvester (site manager) Ms. Charlotte Despres, and sampling officer, Anne Grant, were very helpful and co-operative during pre-survey arrangements. Anne Grant met with the survey team on the Wednesday morning before the oyster sampling was undertaken. Ms. Despres accompanied the team on Wednesday afternoon at low tide to the oyster farm and provided additional information regarding the fishery.

Fishery
The Kyle of Tongue site presently consists entirely of Pacific oyster production although in the past the area was also classified for common mussels. No evidence of mussel harvesting was found during the survey and the local sampling officer noted that there had been no mussel production in that area for over five years.

Ms. Despres informed the team that she has had the site for approximately one year and took over from the previous owner Angela MacKay. At present, there are

somewhere in the region of 26-30 million oysters and 15,000 trestles, with plans to expand in the coming years. At the time of survey, there were very few mature oysters at the site with most of them being juveniles (brought in since June 2013) or only a year old. In each bag of juveniles there were approximately 2000 oysters, then after 1 or 2 years (depending on growth and size), Ms. Despres and her staff distribute the shellfish so that there are 150 oysters per bag. Ms. Despres also explained that the reason for there being so many empty trestles was so that there would be room to re-distribute the shellfish over the next few years as the shellfish grow in size.

At the time of survey, there were only two full rows of trestles of mature oysters, which were leftover stock from the previous site owner. Shellfish were therefore collected from each row of trestles for sampling.

Over the coming years, Ms. Despres expects to have up to 40 million oysters, including juveniles, which will be kept in rotation so that as mature oysters are harvested, at around 3 years old and they will buy in further stock of juveniles from Morecombe. The juveniles are kept furthest from the shore so that they are in the water for longer when the tide goes out so that they feed for a longer period of time and grow faster.

Anne Grant noted that the previous owner had a much smaller oyster fishery with only a few trestles kept on the shore which were easily accessible at low tide.

The survey team observed eight staff members (plus Ms. Despres) and two tractors working on the oyster farm on the day of sampling.

Sewage Sources

The two larger settlements are located in close vicinity of Kyle of Tongue with Midtown to the northwest and Rhitongue to the east. The village of Tongue is approximately two kilometres south of the fishery site. Only a small number of dwellings were observed outside of these small villages as most properties were set further back from the shore and therefore were not visible during the survey. Any dwellings that were observed during the survey were detached private properties. There is a youth hostel, Tongue Lodge, located on the southern shore but no discharge pipes were observed in association with this. Only a small number of pipes were noted on the survey and only one had any discharge, the others all being dry. Details of these can be found in Table 1.

Seasonal Population

There are no campsites or caravan parks noted in the vicinity of Kyle of Tongue nor were any B&Bs or hotels observed apart from the youth hostel, Tongue Lodge, on the southern shore.

Boats/Shipping

There is a pier on the eastern shore of Kyle of Tongue next to Tongue House although no boats or moorings were observed at the time of survey. One mooring was observed from the western shore but no boat was present.

Farming and Livestock
Farming is present around most of the survey area with the majority revolving around sheep grazing and rough pasture. Sheep were observed mainly on the western shore and were either grazing in fields or roaming freely along the shore.

Land Use
The land surrounding Kyle of Tongue is a mixture of agriculture, rough grazing and crofting. Patches of woodland and forestry were seen during the survey although no actual forestry activity was observed. Some arable land and fields of crops were also observed around the shoreline at random and were interspersed by areas of forestry. Surrounding the bay are a small number of detached private dwellings as well as the villages of Midtown, Rhitongue and Tongue.

Land Cover
The majority of the land cover surrounding the Kyle of Tongue is a mixture of rough and improved grassland along with heath and moorland. There were fields for both crops and sheep grazing dispersed mainly on the western shore but also a few on the eastern shore. On the eastern shore there was an area of mixed woodland next to the shoreline and reaching beyond the road. The shoreline on the western shore was mainly sandy beach with a gentle gradient whereas the eastern shore was much steeper with cliffs and a rocky shoreline.

Watercourses
Several small watercourses, with a width of approximately one meter or less, discharge into Kyle of Tongue. Within the survey area, three watercourses were un-named and others included Achuvoldrach Burn on the south western shore, Tongue Burn on the south eastern shore and Strathtongue Burn on the north eastern shore. The largest of watercourse discharging into the Kyle of Tongue was the Achuvoldrach Burn with a width of three and a half meters.

A small number of drainage ditches were also observed along the survey route but these were mainly dry. One had only a small volume of water which was stagnant and so was not sampled.

Wildlife/Birds
Several species of birds were noted during the survey, details of which can be found in Table 1. Geese and seagulls were the most abundant bird species and were seen both on the shore, on the sea and flying overhead. Other than birds, no other wildlife was observed.

Shoreline Survey Maps

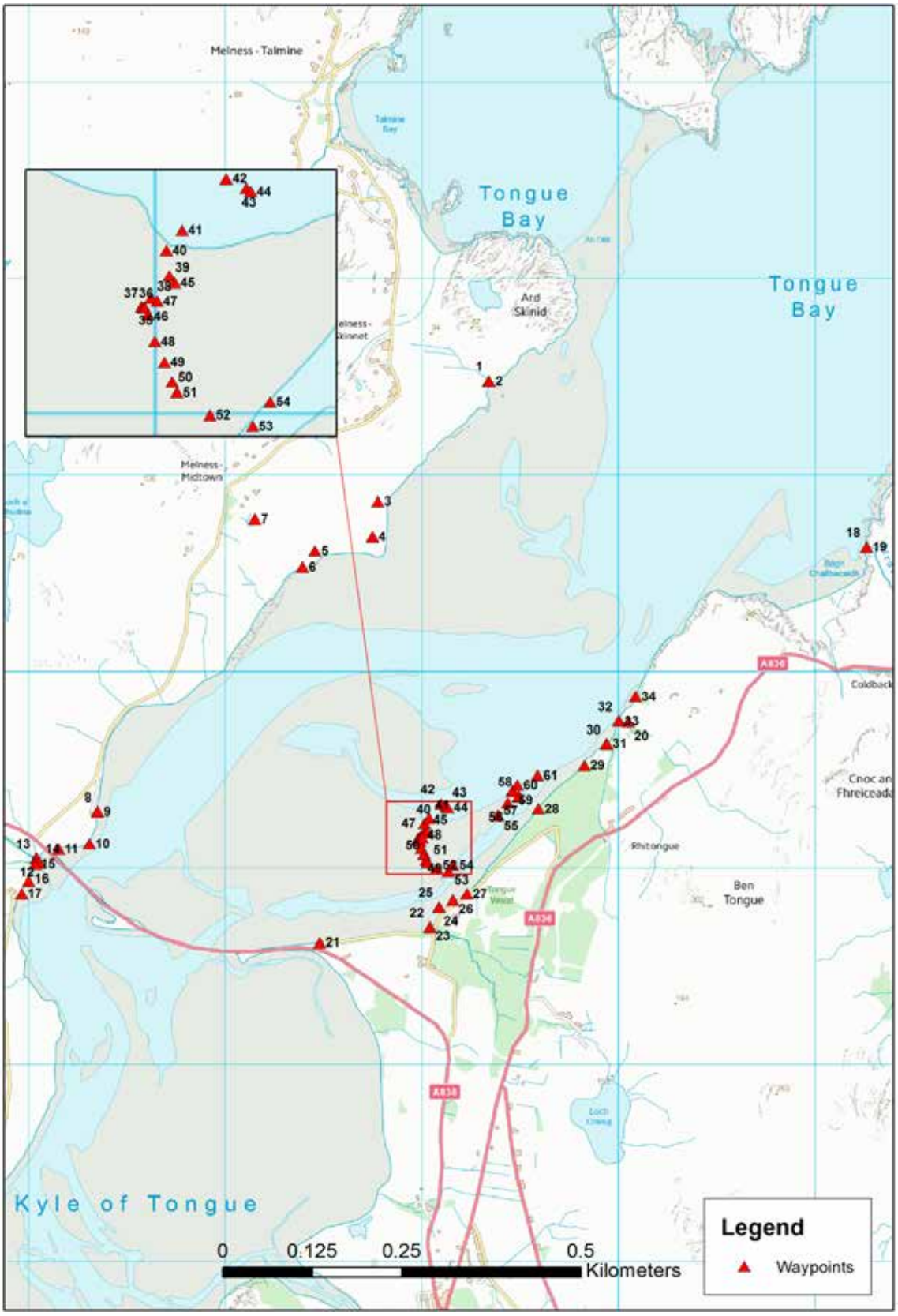


Figure 1. Kyle of Tongue waypoints

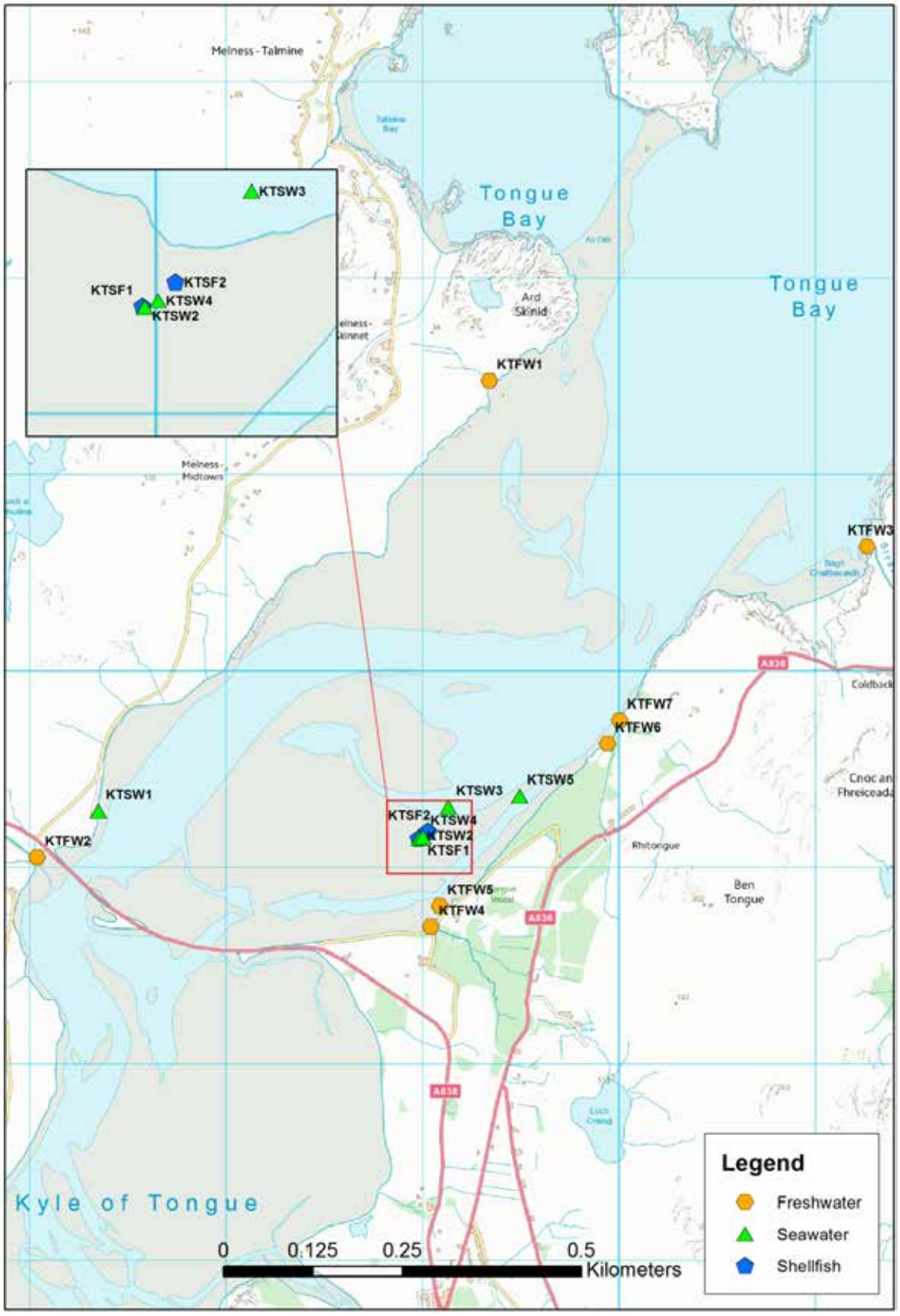


Figure 2. Kyle of Tongue samples

Table 1. Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
1	20/08/2013	8:40	NC 59340 61479	259340	961479	Fig.3	KTFW1	Planned freshwater sample from unnamed watercourse. Sample associated with waypoint 2.
2	20/08/2013	8:41	NC 59343 61477	259344	961478	Fig.3		Watercourse running down towards shore. Width = 44 cm; Depth = 5 cm; Flow = 0.148 m/s; SD = 0.007. Sheep tracks evident, no sheep observed. Sixteen geese overhead.
3	20/08/2013	9:04	NC 58777 60866	258777	960867			Dried out drainage ditch from fields above onto shore. Two sheep in field.
4	20/08/2013	9:10	NC 58749 60686	258749	960686			Two seagulls in water. Lots of cockle shells on shore.
5	20/08/2013	9:17	NC 58456 60615	258456	960615			Dry drainage ditch.
6	20/08/2013	9:21	NC 58392 60533	258393	960533			Seventeen geese overhead.
7	20/08/2013	9:33	NC 58150 60776	258151	960777	Fig.4		Ten sheep in field below farm house back from shore.
8	20/08/2013	10:08	NC 57350 59286	257351	959287	Fig.5	KTSW1	Planned seawater sample. Sample associated with waypoint 9.
9	20/08/2013	10:08	NC 57350 59286	257351	959287	Fig.5		No sign of any sewage outfalls in the area close to sample location. Cemetery is back from shore next to road.
10	20/08/2013	10:12	NC 57309 59125	257310	959125	Fig.6		Twenty sheep and sheep droppings on shore. Three sheep seen on hill in the far distance.
11	20/08/2013	10:16	NC 57153 59097	257153	959097	Fig.7		Boat mooring close to shore, near the main road. No boat present.
12	20/08/2013	10:22	NC 57039 59051	257039	959052		KTFW2	Planned freshwater sample from Achuvoldrach Burn. Sample associated with waypoint 13.
13	20/08/2013	10:22	NC 57040 59050	257040	959051			Burn measurements on one shore: Width = 3.5 m; Depth 1 = 42 cm; Flow 1 = 0.008 m/s; SD 1 = 0.004.
14	20/08/2013	10:28	NC 57056 59027	257056	959027			Burn measurements from opposite shore of river: Depth 2 = 26 cm; Flow 2 = 0.178 m/s; SD 2 = 0.009.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
15	20/08/2013	10:32	NC 57033 59020	257033	959020			Watercourse coming down from field towards shore. Very shallow and stagnant. No sample taken.
16	20/08/2013	10:34	NC 56999 58935	257000	958936			One oyster catcher on shore.
17	20/08/2013	10:37	NC 56965 58870	256965	958870	Fig.8		Pipe running to shore from beside house. Pipe is dry with no flow and has 10cm diameter. No septic tank visible.
18	20/08/2013	11:26	NC 61264 60634	261265	960635	Fig.9	KTFW3	Planned freshwater sample from Strathtongue Burn. Sample associated with waypoint 19.
19	20/08/2013	11:27	NC 61264 60634	261264	960635	Fig.9		Fast moving river (Strathtongue Burn) running through valley onto shore. Width = 43 cm; Depth = 9 cm; Flow = 1.595 m/s; SD = 0.074.
20	20/08/2013	12:20	NC 60050 59744	260051	959745			Failed attempt to access river as ground from this side of the river was too steep and with cliffs along the shore. Access was gained the following day from other side of shoreline (waypoint 32).
21	20/08/2013	13:05	NC 58481 58621	258481	958621	Fig.10		Concrete pipe, 50 cm diameter. No flow. Protrudes from under road onto shore. There is a small round house on shore behind pipe. Approximately ten seagulls on sand.
22	20/08/2013	13:16	NC 59044 58699	259044	958700		KTFW4	Planned freshwater sample from Tongue Burn running under road onto shore. Sample associated with waypoint 23.
23	20/08/2013	13:16	NC 59041 58700	259042	958701			Tongue Burn running under road onto shore. Width = 75 cm; Depth = 10 cm; Flow = 0.005 m/s; SD = 0.008. Green algae growing downstream of river.
24	20/08/2013	13:24	NC 59088 58802	259088	958803	Fig.11	KTFW5	Unplanned freshwater sample taken directly from sewage pipe (contaminated). Sample associated with waypoint 25.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
25	20/08/2013	13:26	NC 59088 58801	259088	958802	Fig.11		Sample taken directly from sewage pipe (contaminated). Metal pipe, situated next to pier, running down onto shore from a property behind. Diameter = 20 cm and approximately 20 m from road. Evidence of raw sewage coming from the pipe with heavy foam build-up. Very strong bad smell. Depth = 1 cm; Approximate flow = 30 ml in 5 secs. Flow rate was estimated by using a graduated container and a watch.
26	20/08/2013	13:35	NC 59159 58838	259159	958839			Location of pier. Oyster beds visible with two tractors and five staff members at present. Two oyster catchers on shore.
27	21/08/2013	8:26	NC 59229 58868	259230	958869			Four herons and eighteen seagulls on shore close to pier.
28	21/08/2013	8:39	NC 59594 59301	259594	959301			Small burn running through wooded area onto shore. No sample taken as the burn was small and deemed low risk as there are no houses, farmland or other obvious sources of potential contamination. Estimated flow = 30 ml / 3 secs; Width = 60 cm; Depth = 2 cm. Flow rate was estimated by using a graduated container and a watch.
29	21/08/2013	8:50	NC 59827 59522	259827	959522			Shoreline inaccessible due to high tide and steep cliffs therefore returned at low tide (waypoint 30).
30	21/08/2013	11:54	NC 59941 59630	259942	959631	Fig.12	KTFW6	Planned freshwater sample from unnamed watercourse. Sample associated with waypoint 31.
31	21/08/2013	11:55	NC 59939 59633	259940	959634	Fig.12		Unnamed watercourse running downhill from wooded area onto shore. Width = 0.75 m; Depth = 10 cm; Flow = 0.014 m/s; SD = 0.005.
32	21/08/2013	12:01	NC 60002 59748	260003	959749	Fig.13	KTFW7	Planned freshwater sample from unnamed watercourse. Sample associated with waypoint 33.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
33	21/08/2013	12:02	NC 60001 59749	260002	959749	Fig.13		Unnamed watercourse running downhill onto shore from steep grassland above. Width = 1.10 m; Depth = 9.5 cm; Flow = 0.106 m/s; SD = 0.003. One seagull on sea and one pigeon on shore.
34	21/08/2013	12:14	NC 60087 59873	260087	959874			No further access along shore. Headland submerged in water and steep cliffs present. Slippery underfoot.
35	21/08/2013	14:19	NC 58980 59149	258980	959149		KTSF1	Planned oyster sample.
36	21/08/2013	14:20	NC 58983 59148	258984	959148		KTSW2	Planned seawater sample.
37	21/08/2013	14:21	NC 58984 59147	258985	959148	Fig.14		SE corner of oyster fishery site.
38	21/08/2013	14:22	NC 58994 59161	258994	959161			Perimeter of oyster fishery site.
39	21/08/2013	14:23	NC 59019 59192	259020	959192			Perimeter of oyster fishery site.
40	21/08/2013	14:23	NC 59015 59227	259015	959227			Perimeter of oyster fishery site.
41	21/08/2013	14:24	NC 59037 59255	259037	959256			Perimeter of oyster fishery site.
42	21/08/2013	14:26	NC 59098 59326	259099	959327	Fig.15		Perimeter of oyster fishery site.
43	21/08/2013	14:27	NC 59126 59313	259126	959314			Perimeter of oyster fishery site.
44	21/08/2013	14:30	NC 59132 59309	259132	959309		KTSW3	Planned seawater sample.
45	21/08/2013	14:35	NC 59026 59182	259027	959183		KTSF2	Planned oyster sample.
46	21/08/2013	14:36	NC 58989 59138	258989	959139			Other end of working trestle.
47	21/08/2013	14:37	NC 59002 59156	259003	959157		KTSW4	Planned seawater sample.
48	21/08/2013	14:39	NC 58999 59100	258999	959101	Fig.16		Perimeter of oyster fishery site.
49	21/08/2013	14:40	NC 59012 59071	259013	959071			Perimeter of oyster fishery site.
50	21/08/2013	14:40	NC 59023 59044	259023	959044	Fig.17		Perimeter of oyster fishery site. Trestles of one year old oysters.
51	21/08/2013	14:41	NC 59029 59029	259030	959030			Perimeter of oyster fishery site.
52	21/08/2013	14:42	NC 59076 58998	259076	958998			Perimeter of oyster fishery site.
53	21/08/2013	14:43	NC 59135 58982	259136	958983			Corner trestle closest to pier.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
54	21/08/2013	14:45	NC 59159 59016	259159	959017			Perimeter of oyster fishery site plus four extra trestles inaccessible for waypointing as submerged in water. The additional four trestles extend the same distance out as the other trestles, as they are all in long rows, but lie approximately 20-30m to the side of the trestles waypointed (see Figure 18). Four oyster catchers on shore.
55	21/08/2013	14:50	NC 59387 59268	259388	959268			Perimeter of oyster fishery site plus four extra trestles inaccessible for waypointing as submerged in water. Same detail as waypoint 54 for the submerged trestles.
56	21/08/2013	14:52	NC 59437 59332	259437	959332			Perimeter of oyster fishery site plus twelve extra trestles inaccessible for waypointing as submerged in water. Same detail as waypoint 54 for the submerged trestles.
57	21/08/2013	14:54	NC 59494 59364	259494	959365	Fig.18	KTSW5	Planned seawater sample.
58	21/08/2013	14:55	NC 59493 59365	259494	959366			SE corner of juvenile oyster beds (juveniles brought to the site in June this year).
59	21/08/2013	14:57	NC 59461 59394	259462	959394			SW corner of juvenile oyster beds
60	21/08/2013	14:58	NC 59485 59422	259486	959423			NW corner of juvenile oyster beds
61	21/08/2013	15:01	NC 59589 59472	259589	959472			NE corner of juvenile oyster beds

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

Sampling

Water samples were collected at sites marked on the Kyle of Tongue map shown in figure 2.

All samples were transferred to Biotherm 10 or Biotherm 30 boxes with ice packs and posted to Glasgow Scientific Services (GSS) for *E. coli* analysis. All samples were posted on the day of collection. Samples KTFW1, KTSW1, KTFW2, KTFW3, KTFW4 and KTFW5 were received and analysed the following day. Samples KTFW6, KTFW7, KTSW2, KTSW3, KTSW4, KTSW5, KTSF1 and KTSF2 were received and analysed two days later. For these samples, a forty eight hour extension was granted due to the time of low tide coinciding with the post office deadline for next day delivery. The sample temperatures on arrival to the laboratory ranged between 0.9 ˚C and 1.1 ˚C.

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

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

Oyster samples were collected by the survey team from the trestles on shore during low tide. As stated in the table above, only two rows of trestles had mature oysters and therefore two shellfish samples were taken instead of the planned three.

KTFW5 was an extra sample acquired which was not on the sample plan. It was taken from an outflow pipe, discharging raw sewage, with a property behind and was therefore classed as a contaminated sample as stated in Table 1 (waypoint 24) above.

Table 2. Water Sample Results

No.	Date	Sample	Grid Ref	Type	*E. coli* (cfu/100ml)	Salinity (ppt)
1	20/08/2013	KTFW1	NC 59340 61479	Freshwater	980	
2	20/08/2013	KTSW1	NC 57350 59286	Seawater	36	35.77
3	20/08/2013	KTFW2	NC 57039 59051	Freshwater	1340	
4	20/08/2013	KTFW3	NC 61264 60634	Freshwater	30	
5	20/08/2013	KTFW4	NC 59044 58699	Freshwater	610	
6	20/08/2013	KTFW5	NC 59088 58802	Freshwater	600000	
7	21/08/2013	KTFW6	NC 59941 59630	Freshwater	330	
8	21/08/2013	KTFW7	NC 60002 59748	Freshwater	320	
9	21/08/2013	KTSW2	NC 58983 59148	Seawater	0	35.59
10	21/08/2013	KTSW3	NC 59132 59309	Seawater	0	35.95
11	21/08/2013	KTSW4	NC 59002 59156	Seawater	2	36.13
12	21/08/2013	KTSW5	NC 59494 59364	Seawater	0	35.95

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	*E. coli* (MPN/100g)
1	21/08/2013	KTSF1	NC 58980 59149	Pacific oyster	<20
2	21/08/2013	KTSF2	NC 59026 59182	Pacific oyster	<20

Photographs

Figure 3. Watercourse running down towards shore. Associated with waypoints 1 & 2. Planned freshwater sample KTFW1.

Figure 4. Ten sheep observed in field below farm house back from shore. Associated with waypoint 7.

Figure 5. Planned seawater sample taken KTSW1. Associated with waypoints 8 & 9.

Figure 6. Sheep faeces on shore. Associated with waypoint 10.

Figure 7. Boat mooring close to shore. Associated with waypoint 11.

Figure 8. Pipe running to shore from beside house. Associated with waypoint 17.

Figure 9. Fast moving river running through valley onto shore. Associated with waypoints 18 & 19. Planned freshwater sample KTFW3.

Figure 10. Concrete pipe protruding under road onto shore with a small round house behind. Associated with waypoint 21.

Figure 11. Metal pipe situated next to pier, running down onto shore from a property behind. Associated with waypoints 24 & 25. Unplanned freshwater sample KTFW5 (contaminated).

Figure 12. River running downhill from wooded area onto shore. Associated with waypoints 30 & 31. Planned freshwater sample KTFW6.

Figure 13. River running downhill onto shore from steep grassland above. Associated with waypoints 32 & 33. Planned freshwater sample KTFW7.

Figure 14. SE corner of oyster fishery site. Associated with waypoint 37.

Figure 15. Perimeter of oyster fishery site. Associated with waypoint 42.

Figure 16. Perimeter of oyster fishery site. Associated with waypoint 48.

Figure 17. Perimeter of oyster fishery site. Associated with waypoint 50.

Figure 18.Planned seawater sample KTSW5. Associated with waypoint 57.