Scottish Sanitary Survey Programme

Sanitary Survey Report

Production Area: Loch Spelve – Croggan Pier

SIN: AB 199 055 13

April 2012

Cefas

Food Standards Agency
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Buidheann Inbhe-Bìdhe

Report Distribution – Loch Spelve

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Table of Contents

I. Executive Summary

The Loch Spelve: Croggan Pier was selected for sanitary survey based on the downgraded classification in 2010-11 of the species harvested (Pacific oyster). Loch Spelve is located on the eastern side of the Isle of Mull off the western coastline of Scotland. The fishery is located in the fairly narrow entrance into the loch. The area around Loch Spelve is sparsely populated with only a few dwellings at Croggan immediately south of the fishery whereas the northern shoreline is uninhabited. The population is likely to increase to some degree during holiday periods.

The Loch Spelve: Croggan Pier fishery consists of Pacific oysters (*Crassostrea gigas*) grown in mesh bags laid on 6 raised, perforated steel beds between two rock groynes, on the intertidal shoreline east of Croggan Pier. Harvesting may occur at any time of year, in accordance with demand. The farm may be expanded deeper into the loch in the future.

Discharges associated with septic tanks along the south shore of the loch lie in close proximity to the oyster fishery and are likely to have an impact on microbiological water quality there. Any impact is likely to be higher when all the homes are occupied, which is more likely to be in the summer months, and dependent on the operational condition of those discharges that go to soakaway. Yachts anchoring off the shore near the fishery are likely to significantly impact water quality at the oyster farm when they are present, as they may discharge septic waste overboard very near the fishery.

A large number of sheep were present on the shoreline south of the fishery during the survey and a large amount of cattle dung was observed along the shore east of the fishery. Due to the numbers of animals and dung seen in close proximity to the fishery, faecal contamination from livestock sources is likely to be a significant contributor to *E. coli* levels found at the fishery.

Wildlife species are likely to contribute to background levels of contamination at the fishery, however it is not possible to estimate their impact due to the limited information available on their numbers and distribution. There is no specific evidence to suggest any one part of the oyster farm is more likely to be affected than another. Seals and birds may either directly deposit faecal material in the vicinity of the oyster farm, or deposit them on shoreline areas where they are later washed into the loch by the tide. Impacts from deer and otters are most likely to be carried via fresh water sources to the waters of the fishery.

Significant correlation between *E. coli* levels in oyster sample results and preceding rainfall was seen and seasonal variation was also found, with higher results occurring during the summer and autumn months. The Allt Frogach watercourse, located <50m south east of the fishery will contribute to *E. coli* contamination in the vicinity of the fishery. Other watercourses may have some impact after heavy rainfall. During heavy rainfall, direct run-off

from the southern shore may carry faecal contamination from animal droppings into the sea near to the oyster farm.

Recommendations

Production area

Production area boundaries should be amended to eliminate areas contained within the Loch Spelve: Rubha na Faing production area. Due to the location and nature of the fishery, it is not possible to exclude potential polluting sources from the production area. Recommended production area boundaries area described as the area bounded by lines drawn between NM 7039 2738 and NM 7039 2781 and between NM 7039 2781 and NM 7100 2739 and extending to MHWS.

Recommended Monitoring Point

As the eastern end of the oyster farm has not historically been monitored, and it lies nearer to the Allt Frogach and the anchorage, it is recommended that the monitoring point be amended to the eastern side of the farm in order to build a picture of contaminant levels at that side of the fishery. Therefore the recommended RMP is NM 7078 2734.

Further information on recommendations relating to sampling depth, tolerance and frequency can be found in the sampling plan and in Section 17 of the report.

II. Sampling Plan

PRODUCTION AREA	Loch Spelve: Croggan Pier
SITE NAME	Croggan Pier
SIN	AB 199 055 13
SPECIES	Pacific oysters
TYPE OF FISHERY	Aquaculture
NGR OF RMP	NM 7078 2734
EAST	170780
NORTH	727340
TOLERANCE (M)	20
DEPTH (M)	Not applicable
METHOD OF SAMPLING	Hand
FREQUENCY OF SAMPLING	Monthly
LOCAL AUTHORITY	Argyll & Bute Council
AUTHORISED SAMPLER(S)	
LOCAL AUTHORITY LIAISON OFFICER	

III. Report

1. General Description

Loch Spelve is located on the eastern side of the Isle of Mull off the western coastline of Scotland. The fishery is located at the inner end of the fairly narrow entrance into the loch approximately 0.5 km in width and 2.4 km in length. This leads in to the main part of the loch which is approximately 7.4 km in length and 2 km in width at its widest point. The Loch Spelve: Croggan Pier was selected for sanitary survey based on species harvested (Pacific oyster) and its downgraded classification in 2010-11.

Figure 1.1 Location of Loch Spelve: Croggan Pier

2. Fishery

The Loch Spelve: Croggan Pier production area consists of a single Pacific oyster (*Crassostrea gigas*) farm located on the south shore of the loch at Croggan. Oysters are grown in mesh bags laid on 6 raised, perforated steel beds between rock groynes on the intertidal shoreline east of Croggan Pier. The racks and bags are pressure washed periodically to keep seaweed, sea squirts and other growth from adhering to the bags and interfering with water flow. Likewise the seabed in the small embayment is kept clear to allow unimpeded flow of water around the site. Harvesting may occur at any time of year, in accordance with demand. The farm may be expanded deeper into the loch in the future.

The current production area boundary is defined by lines drawn between NM 7064 2824 (Rubha na Cille) and NM 7000 2737 and between NM 7290 2747 (Rubha na Faoilinn) and NM 7225 2700 (Rubha na Sailthean). The nominal Representative Monitoring Point (RMP) is reported at NM 7075 2733, which is located at the west end of the shellfish farm.

The actual location of the oyster farm within the loch was recorded during the shoreline survey and is shown together with the production area boundaries, seabed lease, RMP and lease areas, in Figure 2.1.

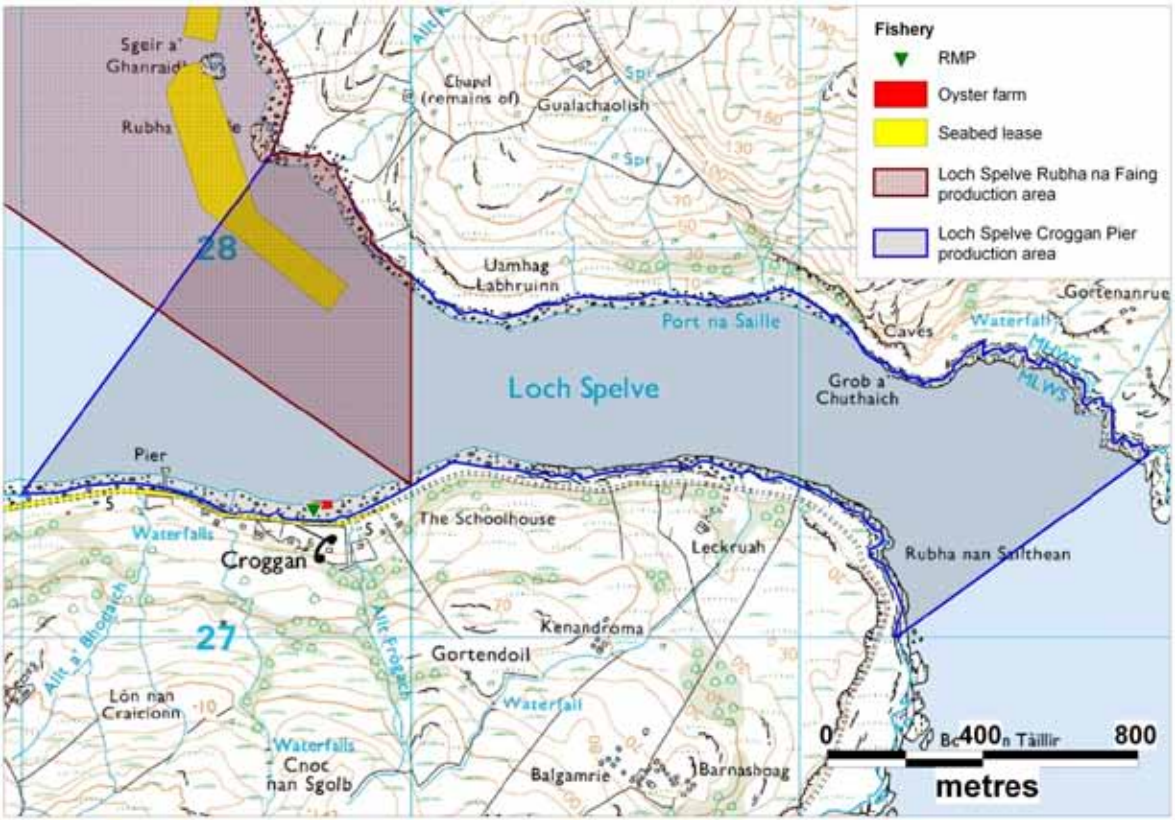

Figure 2.1 Loch Spelve: Croggan Pier Fishery

3. Human Population

Information on the human population of the area around Loch Spelve was obtained from the General Register Office for Scotland. Data was provided for the 2001 census by output area. The population density for the output areas nearest the fishery is shown thematically mapped in Figure 3.1.

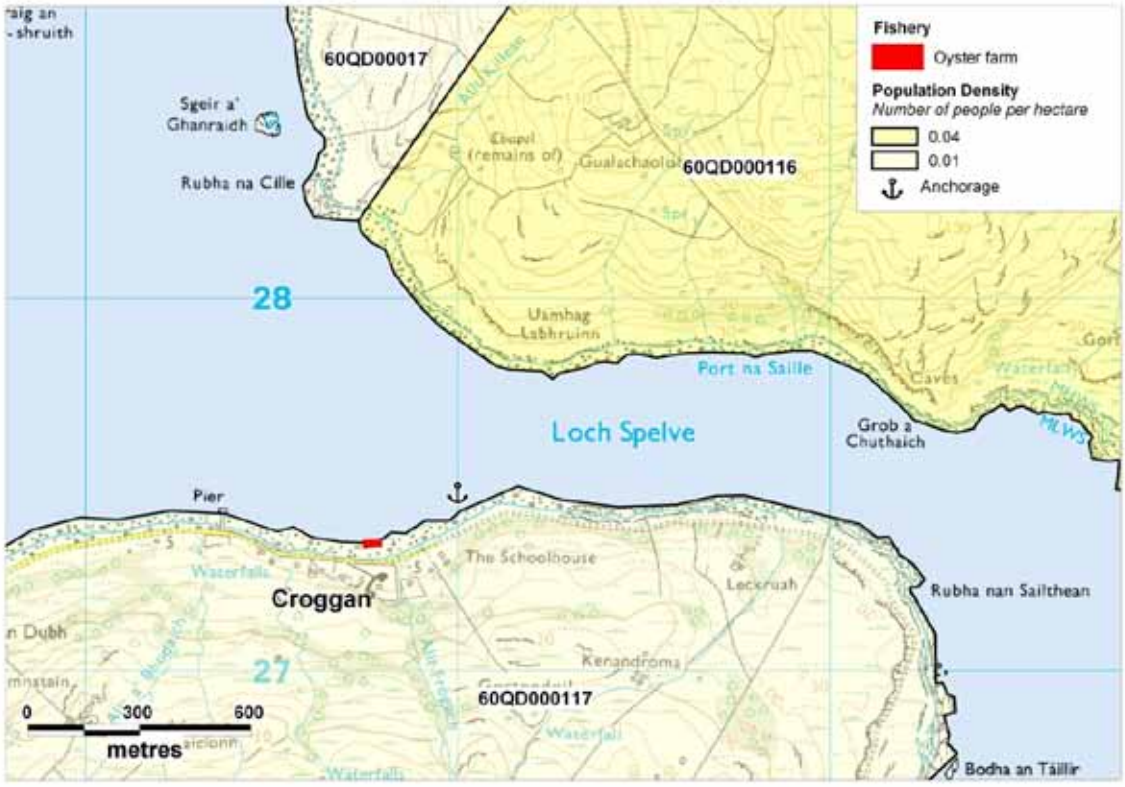

Figure 3.1 Population map of Loch Spelve: Croggan Pier

The area around Loch Spelve is sparsely populated. The shoreline opposite the fishery is inaccessible by road or track and is uninhabited. The shoreline at Croggan is accessible via a road and then track running adjacent to the shoreline. There are seven dwellings at Croggan, three of which are in permanent occupation with the remainder used as holiday lets. During the shoreline survey, campers were observed near Grob a Chuthaich, on the north shore near the entrance to Loch Spelve.

The population of the area surrounding Loch Spelve is spread across two census output areas, listed in Table 3.1.

Table 3.1 Census output areas: Loch Spelve: Croggan Pier

Output area	Population
60RD00016	78
60RD000017	136

In addition to the abandoned pier, a small pontoon jetty is positioned to the west of the fishery. Two fishing boats were observed moored to the jetty

during the shoreline survey. There is an anchorage identified at Croggan, very near the oyster farm (Clyde Cruising Club, 2007), and two pleasure yachts were seen transiting the loch during the shoreline survey.

The population of the area is likely to be higher during holiday periods. Peak holiday season in most areas of Scotland occurs during July and August.

4. Sewage Discharges

No Scottish Water assets were identified for the area surrounding Loch Spelve: Croggan Pier. One discharge consent was provided by SEPA, details of which are listed in Table 4.1. No sanitary or microbiological data were available for this discharge. There has been no historical requirement to register septic tanks in Scotland, therefore there are likely to be additional sanitary systems not identified in Table 4.1.

Table 4.1 Discharge consents identified by SEPA

Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Consented/ design PE	Discharges to
CAR/R/1037898	NM 70887 27211	Sewage	Septic tank	5	Soakaway

Sewage infrastructure recorded during the shoreline survey is listed in Table 4.2.

Table 4.2 Discharges and septic tanks observed during shoreline surveys

No.	Date	NGR	Description
1	31/08/2011	NM 70469 27329	Septic tank discharges to ditch that flows into culvert
2	31/08/2011	NM 70477 27340	Pipe through road, trickling. No odour but black/green algae. Too low to measure, water sample LSC6 taken from puddled area on rock
3	31/08/2011	NM 71807 27304	Septic tank - outflow to land. Part of perforated pipe visible above ground. No odour, house appears unoccupied.

Seven homes line the southern shoreline adjacent to the fishery whereas the northern shore is uninhabited. Only three of these are reported to be permanently occupied, with the remainder used as holiday lets. The harvester, who lives in one of the homes, reported that there is no mains sewerage provision to the area and that the homes are likely to all be on individual septic systems as far as they are aware. Two septic tanks were observed, and one discharge through a culvert under the road that appeared to have septic content. No pipes were observed to discharge directly to the shore. The tank observed at the farmhouse east of the fishery had a perforated pipe (Table 4.2, No. 3) leading from the tank to underground, and is presumed to be on a soakaway. No odour was detected and the house appeared to be unoccupied.

Water samples taken during the shoreline survey indicated some faecal contamination near the fishery. A water sample taken from outflow through the culvert identified in Table 4.2, No. 1 gave a result of 2000 *E. coli*/100 ml, indicating significant faecal content. A freshwater sample was taken downstream of discharge CAR/R/1037898 also showed significant faecal contamination (1200 *E. coli*/100 ml). It is not clear what proportion of this, if any, might have been due to impact from the soakaway system. The consent location plots within 30 m of the Allt Fròg ach, the location of the soakaway field itself was not identified.

Discharges associated with septic tanks along the south shore of the loch lie in close proximity to the oyster fishery and are likely to have an impact on microbiological water quality there. Any impact is likely to be higher during holiday periods when all the homes are occupied.

Although there are potential human sources of human faecal contamination arising both east and the west of the oyster farm, there is insufficient information to identify whether one source or other would be predominant with regard to contamination levels found in Pacific oysters at the Croggan site.

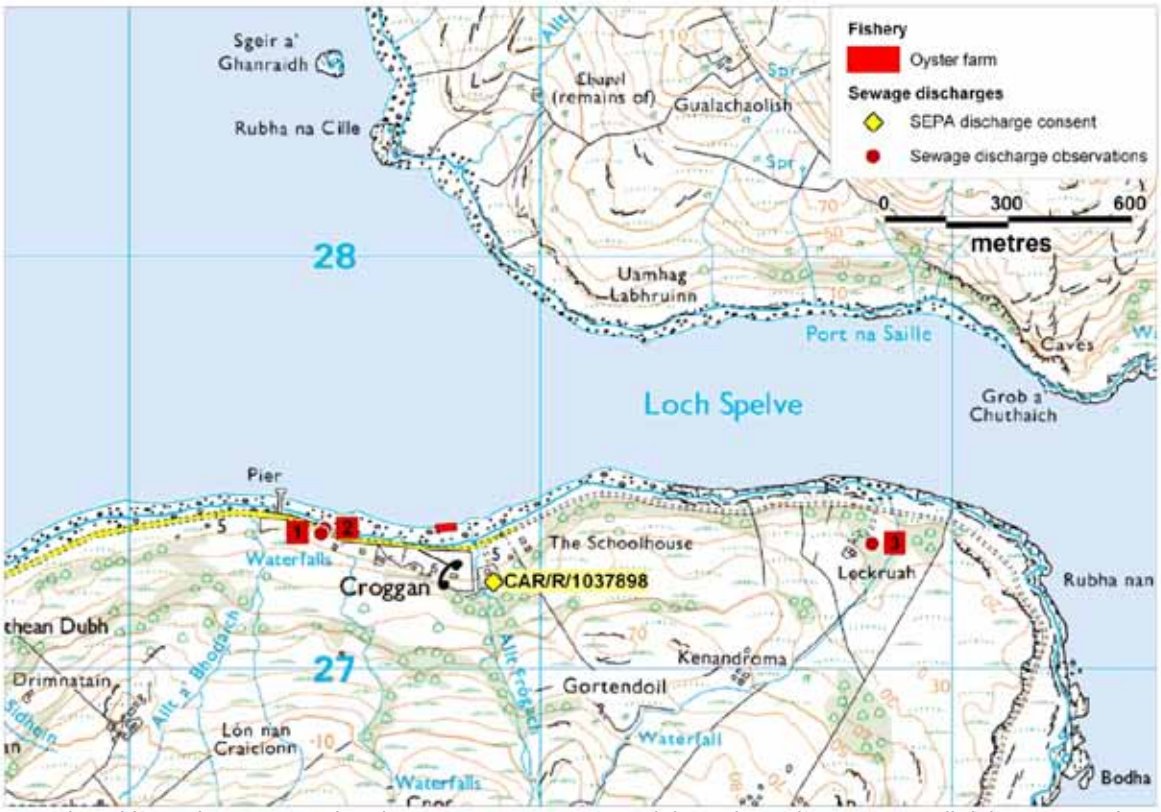

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Figure 4.1 Map of discharges for Loch Spelve: Croggan Pier

5. Geology and Soils

Geology and soil types were assessed following the method described in Appendix 2. A map of the resulting soil drainage classes is shown in Figure 5.1. Areas shaded red indicate poorly draining soils while areas shaded blue indicate more freely draining soils.

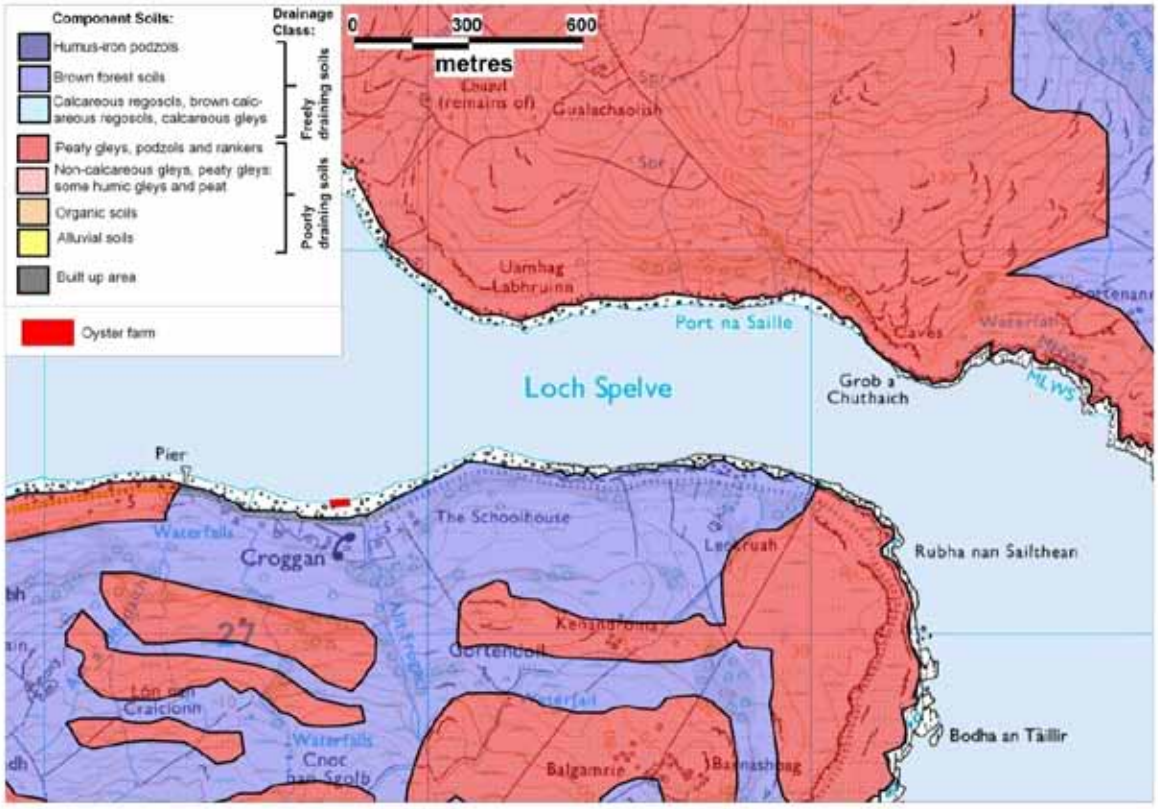

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Figure 5.1 Component soils and drainage classes for Loch Spelve: Croggan Pier

Both freely drained and poorly drained soils are present in this area. Peaty gleys, podzols and rankers are found over the majority of the land north of the fishery. Part of the land south of the fishery, including shoreline areas to the west of the pier and around Rubha nan Sailthean are also comprised of these poorly drained soils. The majority of the land immediately adjacent to the fishery is comprised of brown forest soils, which are classed as freely draining. Parts of the catchments for all the streams located along the south shore contain poorly-drained soils, and therefore the impact from runoff from these to streams may be higher than is represented by the soil types present at their outlets.

The potential for runoff contaminated with *E. coli* from human and/or animal waste is therefore low along the coastline immediately adjacent to the fishery, and higher to the east and west of the fishery, as well as along the entire shore north of the fishery.

6. Land Cover

The Land Cover Map 2000 data for the area is shown in Figure 6.1 below:

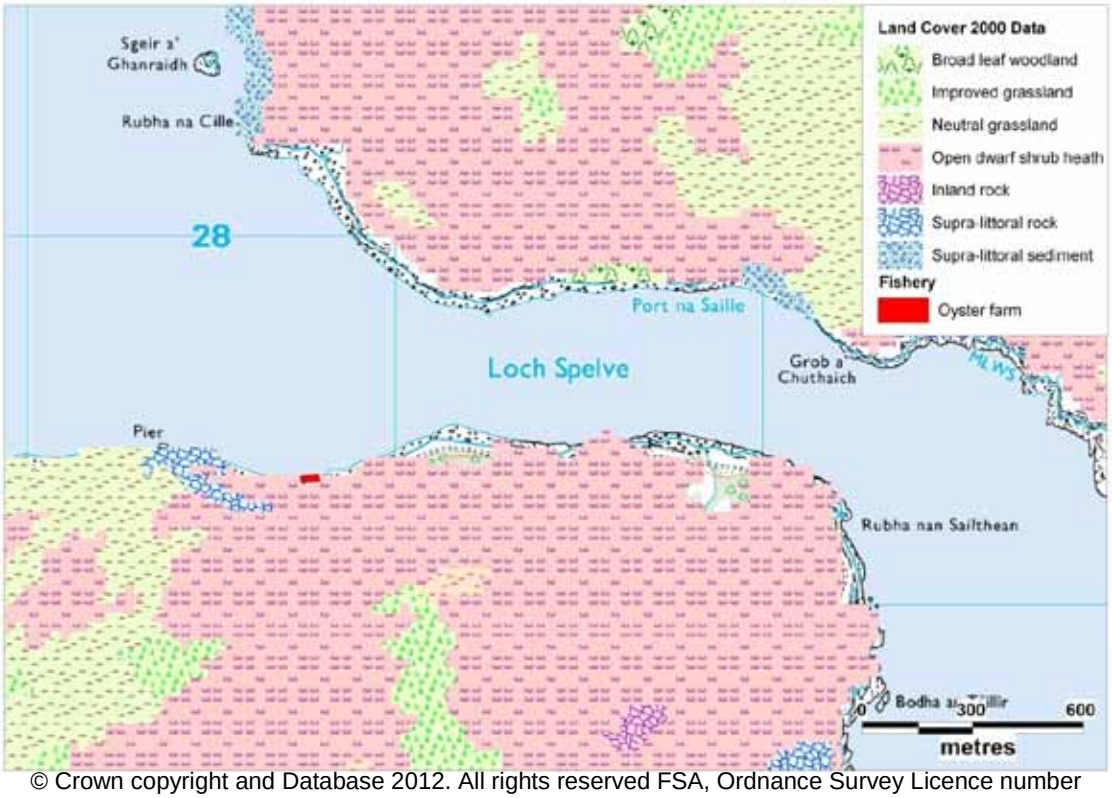

Figure 6.1 LCM2000 class land cover data for Loch Spelve: Croggan Pier

Heath covers much of the land on both sides of the fishery. Large areas of grassland, including improved grassland, extend inland from the south shoreline west of the pier and from the north shoreline at Grob a Chuthaich. Small areas of acid grassland, woodland and rock are also interspersed through the area. Areas of heath and grassland of all types may used for rough grazing. Although not represented in the Landcover 2000 data, an area of improved grassland along the shore south of the oyster farm was identified during the shoreline survey.

Faecal indicator organism export coefficients for faecal coliform bacteria have been found to be approximately $8.3x10^{8}$ cfu km^{-2} hr^{-1} for areas of improved grassland and approximately $2.5x10^{8}$ cfu km^{-2} hr^{-1} for rough grazing (Kay et al. 2008). The contributions from all land cover types would be expected to increase significantly after rainfall events, however this effect would be particularly marked from improved grassland areas (roughly 1000-fold) (Kay et al. 2008).

The highest potential contribution of contaminated runoff to the fishery is from the small area of improved grassland seen during the shoreline survey adjacent to the oyster farm. Heath land around this area utilised for rough grazing is also expected to contribute significantly to faecal contaminant loading carried in watercourses and overland flow draining the area during rainfall.

7. Farm Animals

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 Torosay parish. Reported livestock populations for the parishes in 2009 and 2010 are listed in Table 7.1. 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 7.1 Livestock numbers in Torosay parish 2009 - 2010

	Torosay 367 km^2			
	2009		2010	
	Holdings	Numbers	Holdings	Numbers
Pigs	*	*	*	*
Poultry	8	194	7	200
Cattle	12	911	11	883
Sheep	16	12194	15	12522
Other horses and ponies	6	15	6	15

The Torosay agricultural parish encompasses much of the southern half of the Isle of Mull and covers over one third of the land area of the island. Large numbers of sheep are kept within the parish, with much smaller numbers of cattle and other livestock. However, it is the number of animals kept within the catchment and near shore of the fishery that will be most likely to affect water quality there.

The only significant source of spatially relevant information on livestock population in the area was the shoreline survey (see Appendix 6), which only relates to the time of the site visit on 31st August 2011. 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 7.1.

A large number of sheep were present on the shoreline south of the fishery during the survey. The harvester reported that the animals had been brought down the day before and lambs were being separated from the ewes in preparation for shipment to market. According to the harvester, sheep are only brought down to the pastures along the Croggan shoreline a few times a year and most of the time are grazed further afield.

A large amount of cattle dung was observed along the shore east of the fishery, though no cattle were seen at the time. The sampling officer reported

that cattle were sometimes present on the shoreline immediately adjacent to the fishery and that the harvesters undertook to move the cattle on when they found them there. The catchment for the area extends northward along a number of burns, and these areas away from the immediate shoreline were not viewed.

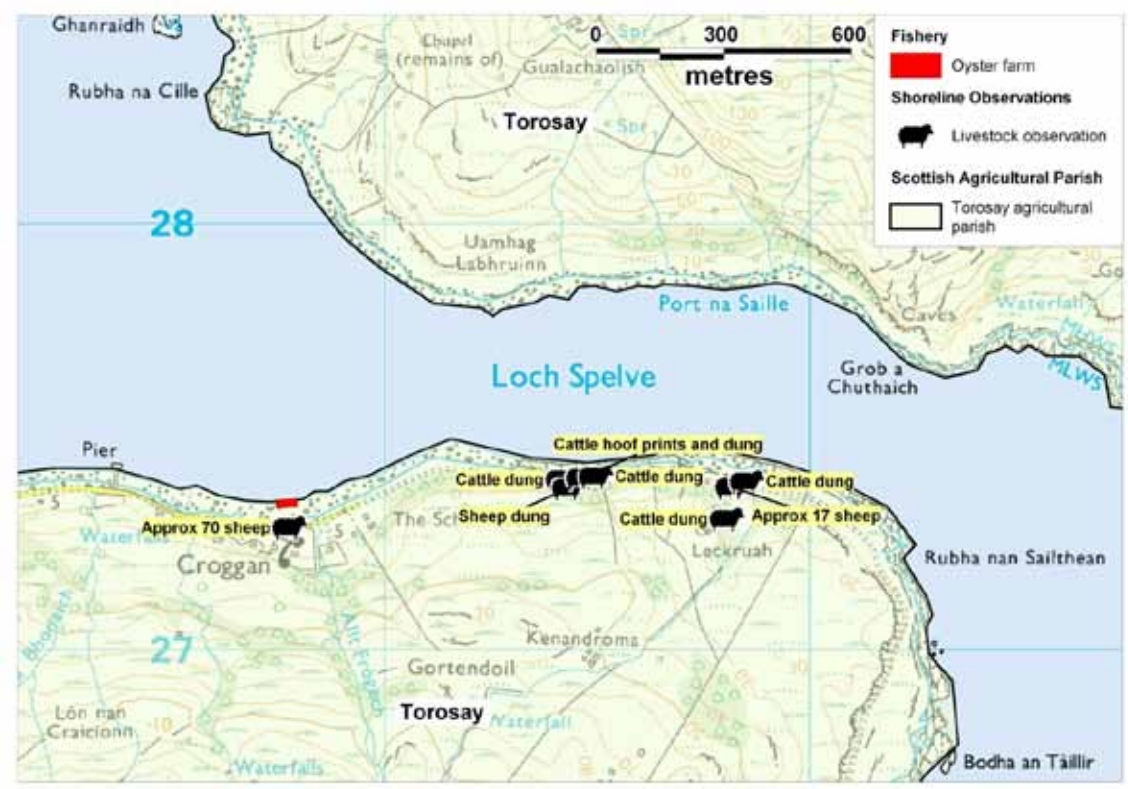

Figure 7.1 Livestock observations at Loch Skipport: Croggan Pier

Due to the numbers of animals and dung seen in close proximity to the fishery, faecal contamination from livestock sources is likely to be a significant contributor to *E. coli* levels found at the fishery. The highest impact to the fishery is likely to come from the shore immediately adjacent when sheep or sheep droppings are present. Faecal contamination arising from cattle and sheep grazed to the east of the fishery would impact the oyster farm on the incoming tide, though these would potentially be subject to higher dilution.

8. Wildlife

Wildlife may contribute to faecal contamination observed at the fishery. General information on the impacts of wildlife species can be found in Appendix 2. The entire shoreline surrounding Loch Spelve falls within the Cnuic agus Cladach Mhuile (Mull Coast and Hills) Special Protected Area (SPA), designated for aggregations of internationally important breeding birds, (Golden eagle (*Aquila chrysaetos*)). Parts of the shoreline of Loch Spelve including areas to the east and west of the fishery fall within the Mull Oakwoods Special Area of Conservation (SAC) designated for the internationally important species (Otter (*Lutra lutra*)) and habitats (http://www.snh.org.uk/pdfs/strategy/GEConsult/4.6.1-MULLCITATION-B440416.pdf, Accessed 09/03/2012). The shoreline north of the fishery falls within the Ardura – Auchnacraig Site of Special Scientific Interest (SSSI), designated for saltmarsh, igneous petrology, upland oak woodland and butterflies.

Wildlife species most likely to contribute to faecal contamination of the waters of Loch Spelve include otters, birds, deer and seals.

Birds
Seabird 2000 observations were queried for a 5 km radius of the Loch Spelve: Croggan Pier oyster farm. No observations of breeding seabirds were recorded for this area. However, there were records outside the area and seabirds nesting elsewhere may use the loch for feeding.

Loch Spelve falls within the boundaries of the Mull Coast and Hills SPA, which had 14 breeding pairs of Golden eagle (*Aquila chrysaetos*), representing approximately 3.3% of the GB population in 2002 (http://www.snh.org.uk/pdfs/strategy/GEConsult/4.6.1-MULLCITATION-B440416.pdf).

The areas of grassland, particularly the improved areas at Crogan, may attract greylag geese, which are present elsewhere on Mull (Mitchell *et al*, 2010) and feed on grass. Gulls and shorebirds are reported to breed around Loch Spelve and wading birds, sea ducks and other seabirds are reported in the area (Spellman, 2012). No information was obtained on the numbers of these animals likely to be present in Loch Spelve. There is seasonal variation in species present, as some are resident and others migrant. There was insufficient information available on which to base an estimate of numbers, however birds are likely to be a contributing source to background contamination levels around the loch throughout the year.

Few birds were seen during the shoreline survey, with only 9 gulls recorded at the west end of the fishery.

Seals
Both grey seals (*Halichoerus grypus*) and common or harbour seals (*Phoca vitulina vitulina*) are recorded in Scotland, and are common around the coastline of the Isle of Mull. Surveys of both species undertaken in 2007 and 2008 showed fewer than 20 common seals and no grey seals observed hauled out in Loch Spelve. Grey seals were, however, present on the

southwest tip of Mull and in the outer Firth of Lorn. These animals are present in the area year-round and forage widely for food. Therefore, they are presumed to be present in or around the waters of the fishery at least part of the time and are likely to contribute to background levels of faecal contamination in the areas where they are found. No seals were seen during the shoreline survey.

Otters

Otters (*Lutra lutra*) are present in the area surrounding Loch Spelve and the Mull Oakwoods SAC was secondarily identified for the presence of otters there.

During the shoreline survey an otter latrine and an otter were observed near the shore east of the fishery during the survey. Otters typically defecate in established latrines adjacent to freshwater courses. Loch Spelve has a number of streams and burns that may host otters, and any faecal contamination from these animals is likely to be carried in the streams.

Deer

Deer are present throughout much of Scotland in significant numbers. The Isle of Mull has an estimated deer population of approximately 9000, which equates to almost 3 deer to every person on the island (http://madeonmull.co.uk/about-mull/).

During the shoreline survey no deer or deer droppings were observed on the shoreline adjacent to the oyster farm. Faecal indicator bacteria arising from deer droppings are likely to be carried via rainfall runoff to rivers and streams.

Conclusions

Wildlife species are likely to contribute to background levels of contamination at the fishery, however it is not possible to estimate their impact due to the limited information available on their numbers and distribution. Seals and birds may either directly deposit faecal material in the vicinity of the oyster farm, or deposit them on shoreline areas where they are later washed into the loch by the tide. Impacts from deer and otters are most likely to be carried via fresh water sources to the waters of the fishery. It is likely that these animals contribute to background levels of contamination found throughout the loch, however there is no specific evidence to suggest any one part of the oyster farm is more likely to be affected than another.

Figure 8.1 Wildlife observations and designations at Loch Spelve

9. Meteorological data

The nearest weather station for which rainfall data was available is located at Mull: Gruline, situated approximately 19 km to the north west of the production area. Rainfall data was available for 2003-2010; however data for the following periods was missing: September 2004, October 2006 and December 2006. The nearest wind station is Tiree, located 73 km west of the production area. Conditions may differ between this station and the fisheries due to the large distances between them. However, this data is still shown as it can be useful in identifying seasonal variation in wind patterns.

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

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 (e.g. 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 *.

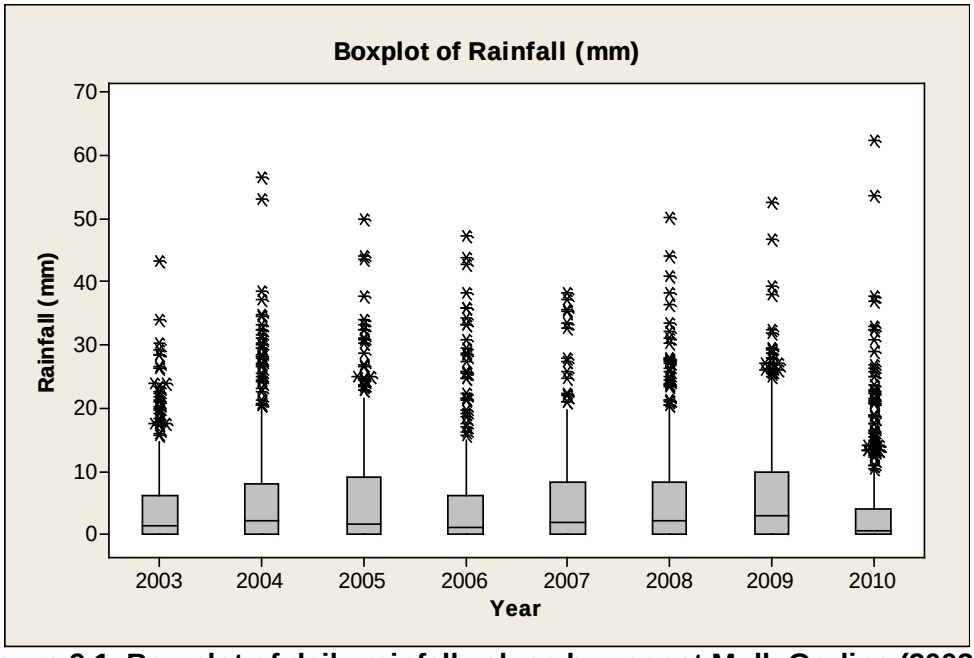

Figure 9.1 Box plot of daily rainfall values by year at Mull: Gruline (2003 – 2010)

Daily rainfall values varied from year to year, with 2010 being the driest year. Although 2006 also appeared to be dry, two months were missing from the dataset and therefore no conclusions can be drawn regarding the annual data. The wettest year was 2009.

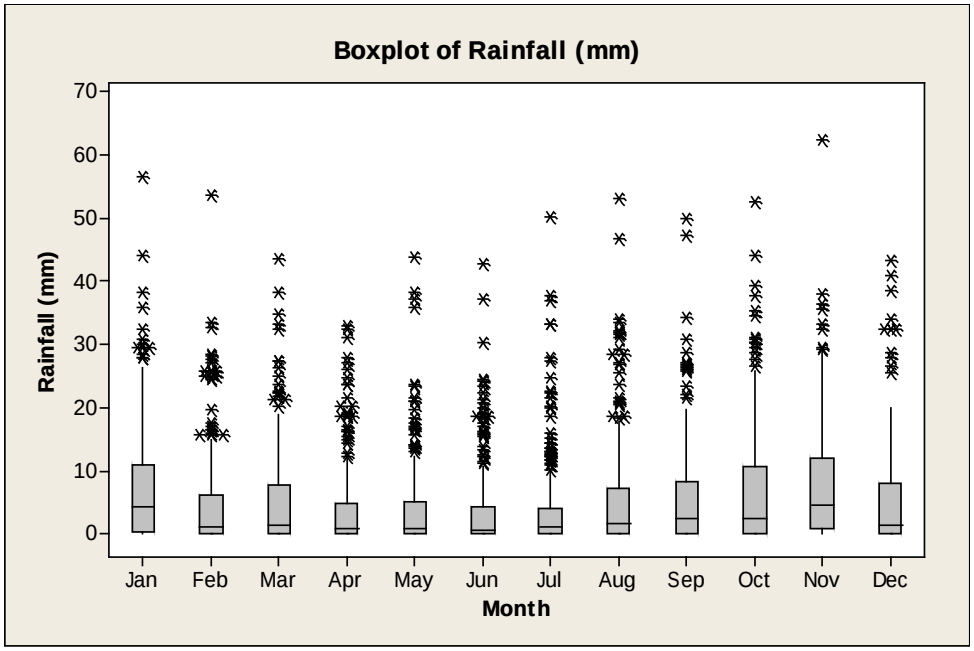

Figure 9.2 Box plot of daily rainfall values by month at Mull: Gruline (2003 – 2010)

Daily rainfall values were higher during the autumn and winter. Rainfall increased from August onward and was highest in November and January. Weather was drier from February to July. Caution should be exercised in assessing this data due to the missing records. The months with missing data fell in the last four months of the year, and therefore autumn rainfall values may be skewed.

For the period considered here (2003 – 2010) 44% of days received daily rainfall of less than 1 mm and 19% of days received rainfall of over 10 mm.

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

9.2 Wind

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

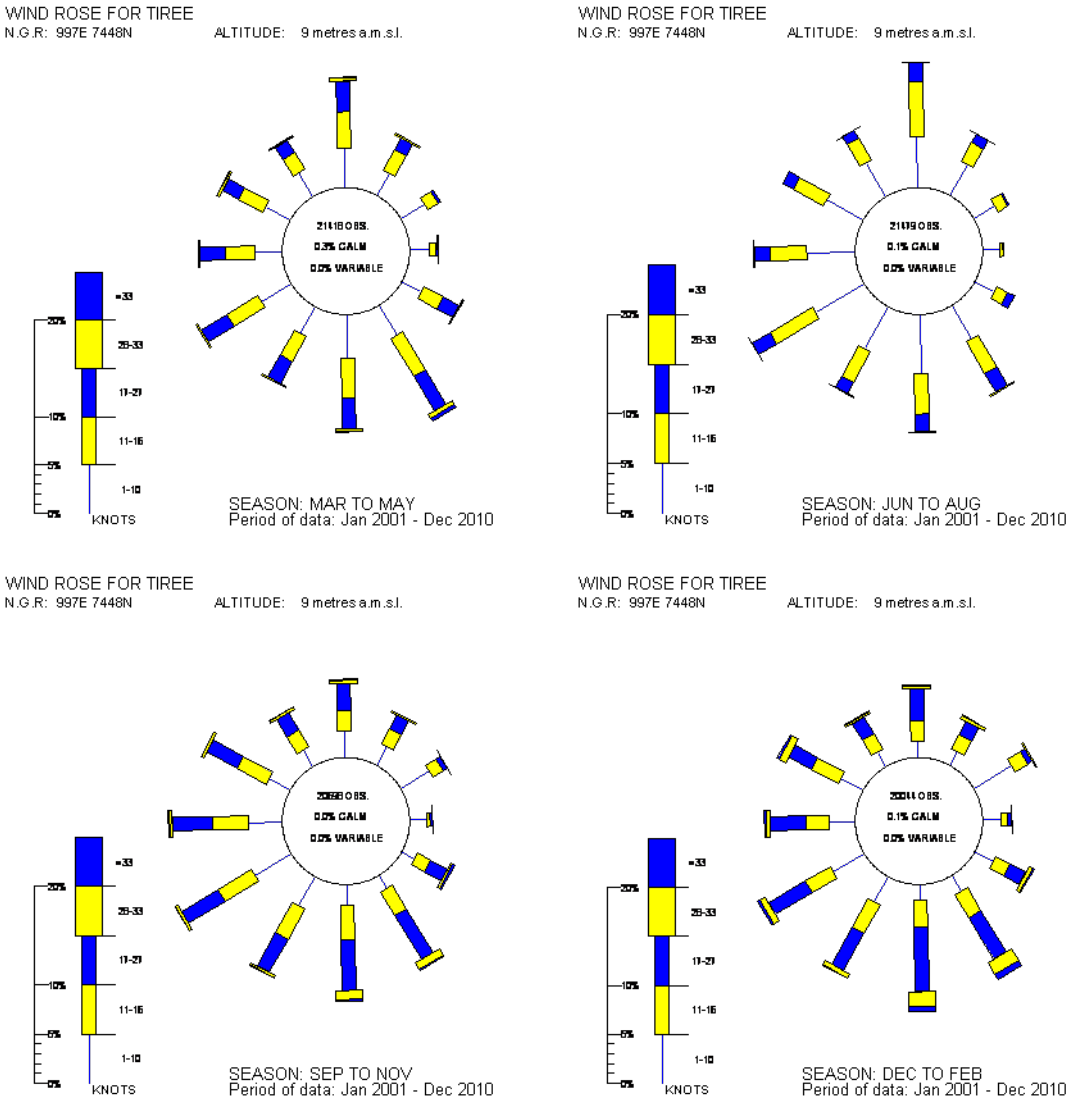

Figure 9.3 Seasonal wind roses for Tiree

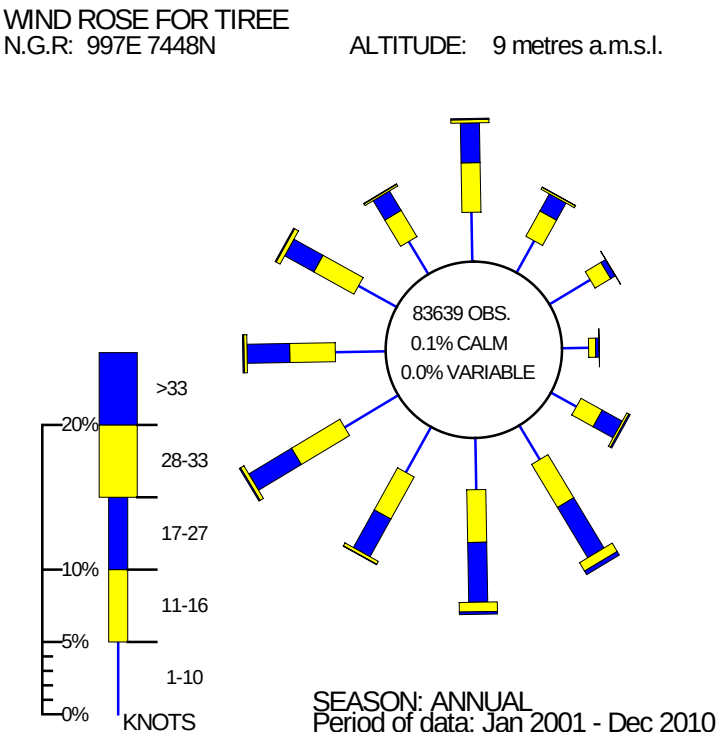

Figure 9.4 Annual wind rose for Tiree

Overall the annual wind direction showed that wind was stronger when coming from the west than the east, and winds from the southerly direction were stronger than those from the north. There was no marked change in wind direction throughout the months; however winds were much stronger in the winter months than in the summer months.

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

10. Current and historical classification status

The Loch Spelve: Croggan Pier fishery was first given a classification for Pacific Oysters (*Crassostrea gigas*) in 2004. The historical and current classifications for the area are shown below in Table 10.1.

Table 10.1 Loch Spelve: Croggan Pier Pacific Oysters

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
2004	A	A	A	A	A	A	A	A	A	A	A	A
2005	A	A	A	A	A	B	B	B	B	B	B	A
2006	A	A	A	A	A	B	B	B	B	B	B	A
2007	A	A	A	A	A	B	B	B	B	B	B	B
2008	A	A	A	A	A	B	B	B	B	B	A	A
2009	A	A	A	A	A	B	B	B	B	B	A	A
2010	A	A	A	A	A	B	B	B	B	B	B	B
2011	A	A	A	A	A	A	B	B	B	B	B	B
2012	A	A	A									

For all but one year (2005) the production area has held a B classification through the summer and autumn months. In three years, this extended to December.

11. Historical *E. coli* data

11.1 Validation of historical data

The results for all samples assigned against Loch Spelve: Croggan Pier from 1st January 2007 up to the 31st December 2011 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 in April 2012. All *E. coli* results were reported as most probable number per 100 g of shellfish flesh and intravalvular fluid.

One sample was recorded on the database as "Rejected" and was deleted. One sample had no result recorded on the database and the sample submission form identified a void result, therefore it was deleted. All samples were received at the laboratory within 48 hours of collection. The reported coolbox temperatures were all between 1 and 8°C. Twelve samples had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation. One sample had a result reported as >18000 and was assigned a value of 36000 for statistical assessment and graphic presentation.

11.2 Summary of microbiological results

Table 11.1 Summary of historical sampling and results

Sampling Summary	
Production area	Loch Spelve: Croggan Pier
Site	Croggan Pier
Species	Pacific oysters
SIN	AB 199 055 13
Location	Various
Total no of samples	54
No. 2007	8
No. 2008	11
No. 2009	12
No. 2010	12
No. 2011	11
Results Summary	
Minimum	<20
Maximum	>18000
Median	70
Geometric mean	86.49
90 percentile	1300
95 percentile	2400
No. exceeding 230/100g	12 (22%)
No. exceeding 1000/100g	7 (13%)
No. exceeding 4600/100g	2 (4%)
No. exceeding 18000/100g	1 (2%)

11.3 Overall geographical pattern of results

One sample was taken from adjacent to Croggan Pier in early 2007. Subsequent samples, all recorded to 1 metre accuracy, were taken from within a 15 m x 5 m area on the western side of the oyster farm.

The reported sampling locations are plotted on the map shown in Figure 11.1 with an inset map showing the size of the symbols graduated by the *E. coli* result.

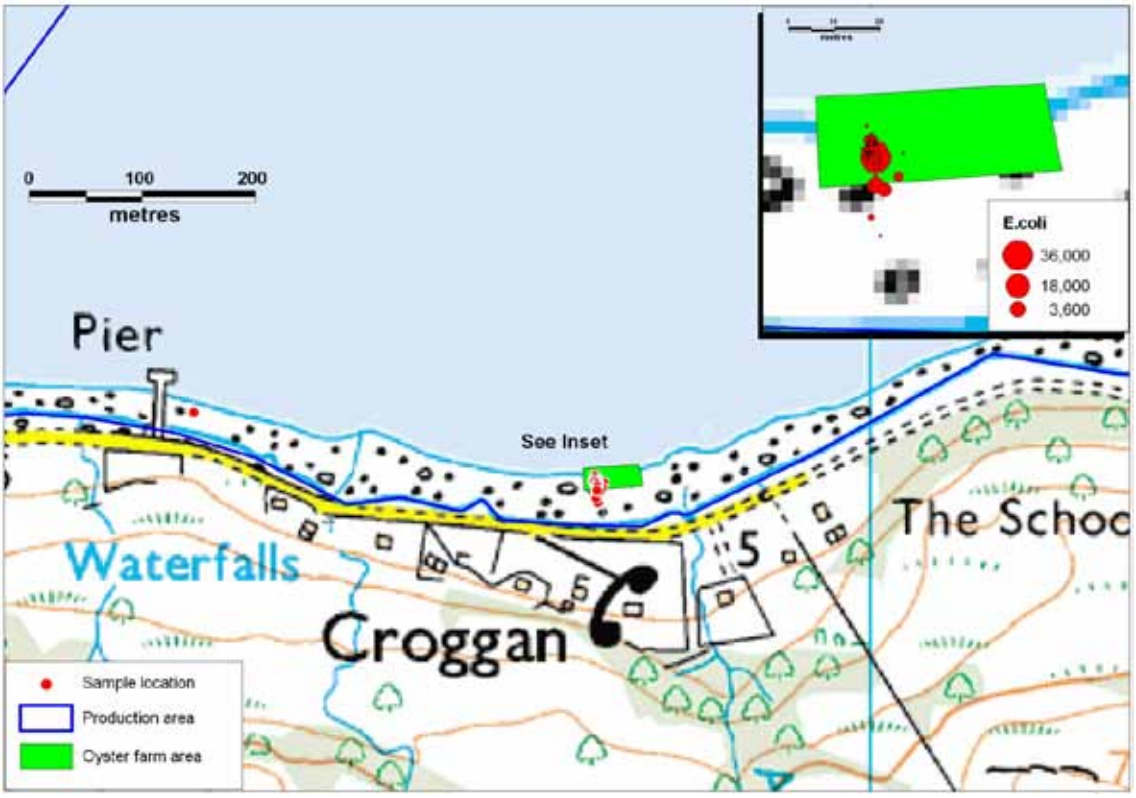

Figure 11.1 Sampling locations and *E. coli* monitoring results at Croggan Pier

Only one sample came from a location that is clearly outwith the small sampling area described above. Within the area sampled, there were no clear patterns of spatial variation in contamination.

11.4 Overall temporal pattern of results

Figure 11.3 presents a scatter plot of individual *E. coli* results against date, for each of the three production areas, fitted with loess smoother lines. Loess stands for 'locally weighted regression scatter plot smoothing'. At each point in the data set an estimated value is fit 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 loess line is influenced more by the data close to it (in time) and less by the data further

away. The smoother line helps to highlight any apparent underlying trends or cycles.

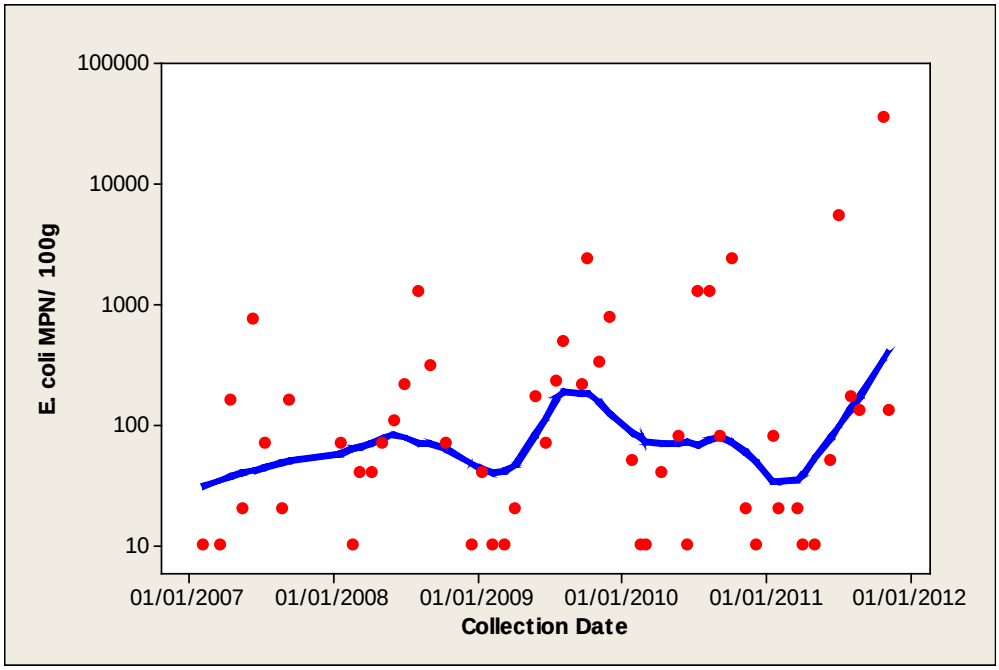

Figure 11.2 Scatterplot of *E. coli* results by date

The trendline in Figure 11.2 suggests a slight increase in results over the time period studied, with peak results increasing over the years. Peaks in results appear to occur approximately during the middle of each year, suggesting a seasonal cycle to results.

11.5 Seasonal pattern of results

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns of human occupation. All of these can affect levels of microbial contamination, and cause seasonal patterns in results. Figure 11.3 presents a scatterplot of *E. coli* result by month superimposed with a Loess smoother line to highlight any trends. A small amount of 'jitter' has been introduced along the X axis so that it is possible to see multiple points at one location on the graph

A strong trend toward higher results during the latter half of the year is apparent in Figure 11.3. Results greater than 230 *E. coli* MPN/100 g occurred from June to December, and the highest results occurred in July and October. Lowest results were seen in February.

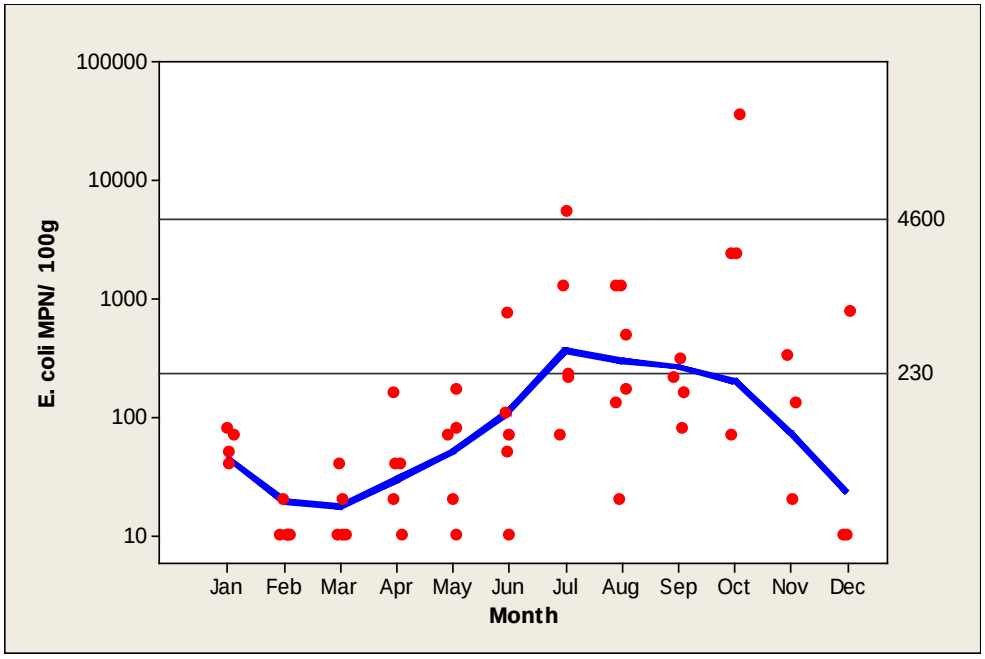

Figure 11.3 Scatterplot of *E. coli* results by month

For statistical evaluation, seasons were split into spring (March - May), summer (June - August), autumn (September - November) and winter (December - February). A boxplot of the results by season is presented in Figure 11.4.

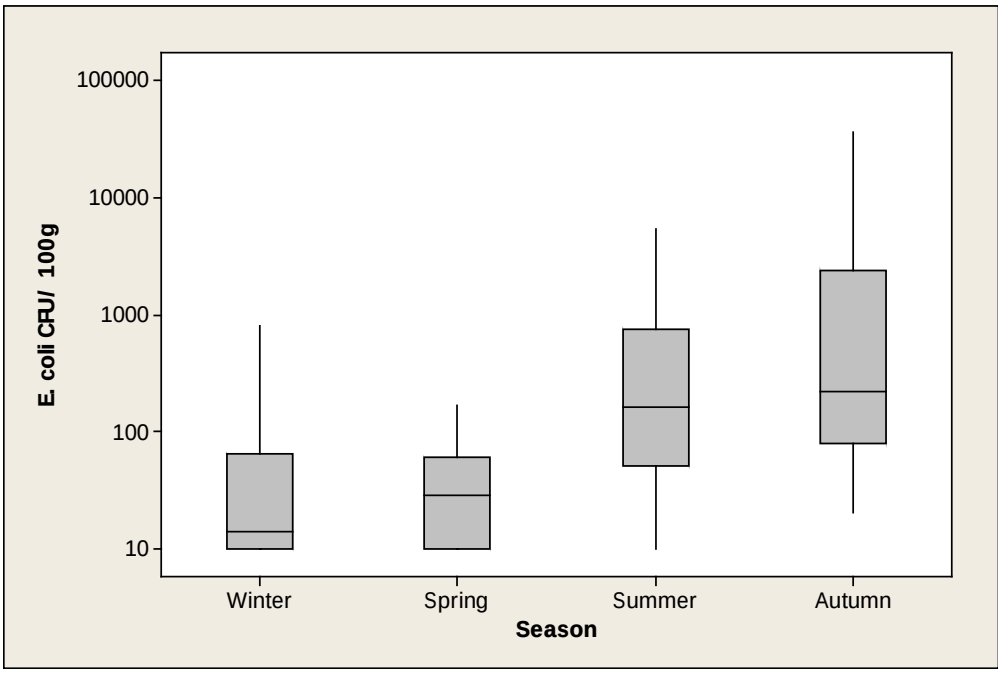

Figure 11.4 Boxplot of result by season

A significant difference was found between results by season (One-way Anova = 9.60, p = <0.001, Appendix 4). A post-ANOVA test (Tukey's comparison, Appendix 4) indicated that the results were higher in summer and autumn than in winter and spring.

11.6 Analysis of results against environmental factors

Environmental factors such as rainfall, tides, winds, sunshine and temperatures can all influence the flux of faecal contamination into growing waters (e.g. 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 Meteorological Office weather station for which rainfall data was available is Mull: Gruline, approximately 19 km northwest of the production area. Rainfall data was purchased from the Meteorological Office for the period up to 31/12/2010 (total daily rainfall in mm). This analysis covers only E. coli monitoring results for the period for which rainfall data was available.

Two-day antecedent rainfall

A scatter plot of *E. coli* results against total rainfall recorded in the two days prior to sampling is presented in figure 11.5.

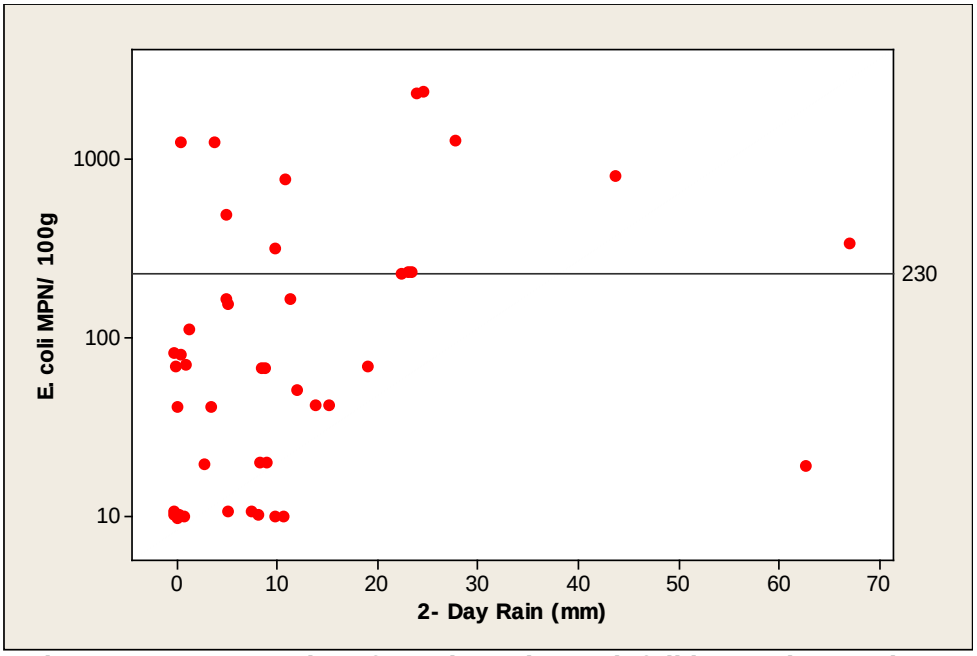

Figure 11.5 Scatterplot of result against rainfall in previous 2 days

A statistically significant positive correlation was found between *E. coli* results and 2-day rainfall (Spearman's rank correlation = 0.421, p = 0.005). However, high results occurred after low and moderate rainfall though the lowest results only occurred at rainfall values of 10 mm or less.

Seven-day antecedent rainfall

As the effects of heavy rain may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationship between

rainfall in the previous 7 days and sample results was investigated in an identical manner to the above. A scatter plot of *E. coli* results against seven day rainfall is shown in Figure 11.6.

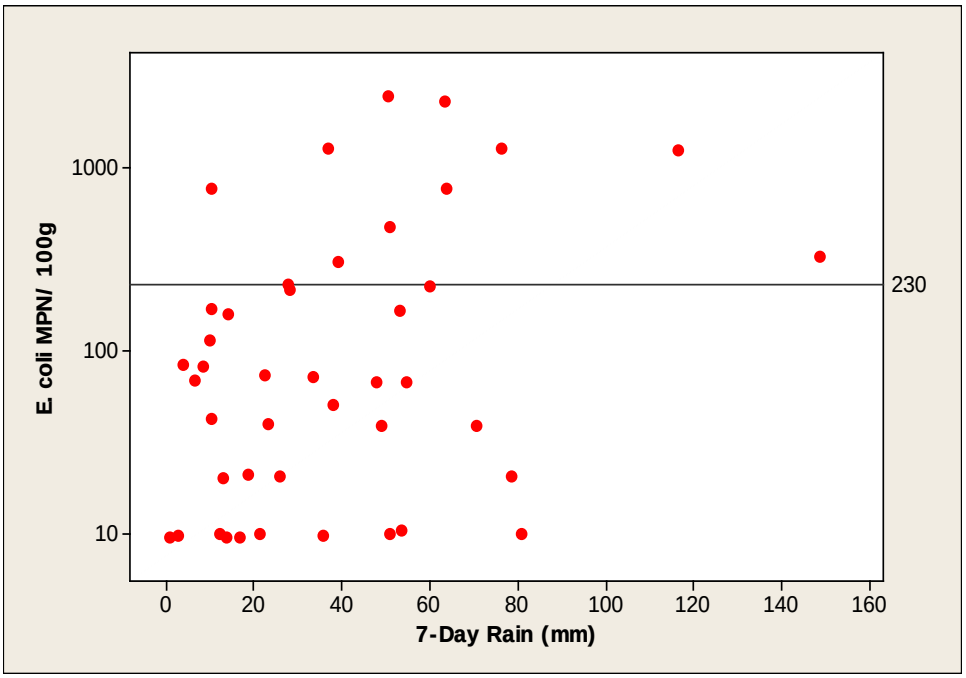

Figure 11.6 Scatterplot of result against rainfall in previous 7 days

A statistically significant positive correlation was found between *E. coli* results and 7-day rainfall (Spearman rank correlation = 0.313, p = 0.041). However, as was seen with Figure 11.5, both now and high results occurred over a broad range of rainfall values and results exceeding 230 *E. coli* MPN/100 g occurred after cumulative 7-day rainfall of just over 10 mm. Few samples were taken at rainfall totals exceeding 80 mm over the 7 days prior to sampling.

11.6.2 Analysis of results by tidal height and state

Spring/Neap tidal cyle

When the larger (spring) tides occur every two weeks, circulation of water and particle transport distances will increase, and more of the shoreline will be covered at high water, potentially washing more faecal contamination from livestock into the area. Figure 11.7 presents a polar plot of $\log_{10}$ *E. coli* results on the lunar spring/neap tidal cycle. Full/new moons are located at 0º, and half moons at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. It should be noted that local meteorological conditions such as wind strength and direction can influence the height of tides and this is not taken into account.

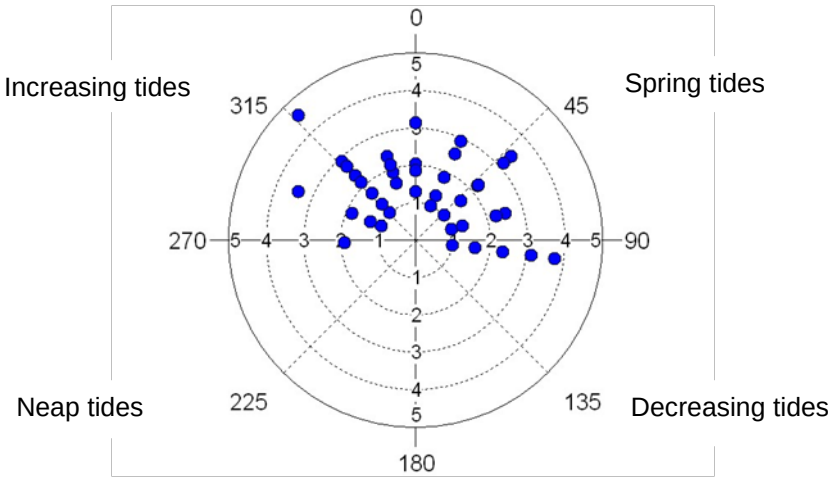

Figure 11.7 Polar plot of log_{10} *E. coli* results on the spring/neap tidal cycle

There was no statistically significant correlation between *E. coli* results and the spring/ neap tidal cycle (Circular linear correlation = 0.139, p = 0.371). Samples were taken from shortly after neap tides to shortly after spring tides. There was no clear trend toward higher results at any point within that range.

High/Low tidal cycle

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the farms during this cycle. As *E. coli* levels in some shellfish species can respond within a few hours or less to changes in *E. coli* levels in water, tidal state at time of sampling (hours post high water) was compared with *E. coli* results. Figure 11.8 presents a polar plot of log_{10} *E. coli* results on the lunar high/low tidal cycle. High water is located at 0º, and low water at 180º.

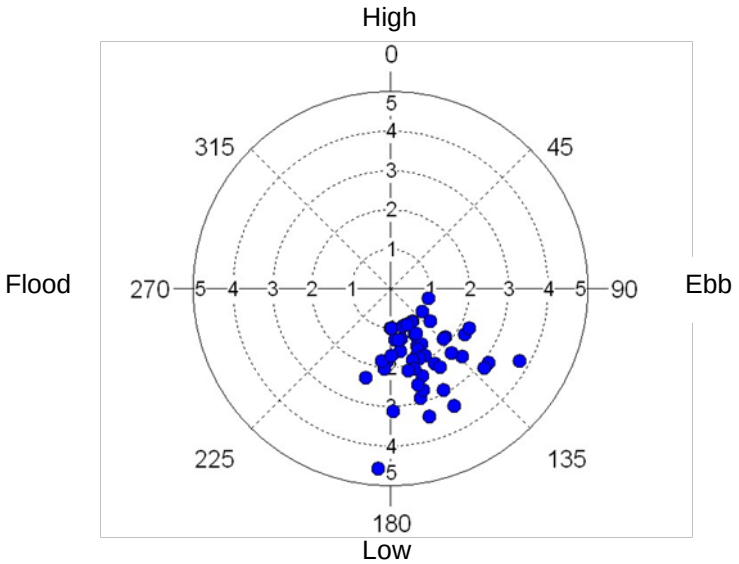

Figure 11.8 Polar plot of log_{10} *E. coli* results on the high/low tidal cycle

There was no statistically significant correlation between *E. coli* results and the high/low tidal cycle (Circular linear correlation = 0.105, p = 0.567). All samples were taken from mid-ebb to just after low tide, and there was no trend toward higher results at any point within that range.

11.6.3 Analysis of results by water temperature

Water temperature is likely to affect the survival time of bacteria in seawater (Burkhardt *et al*, 2000) and the feeding and elimination rates of shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. It is of course closely related to season, and so any correlation between temperatures and *E. coli* levels in shellfish flesh may not be directly attributable to temperature, but to other factors such as seasonal differences in livestock grazing patterns.

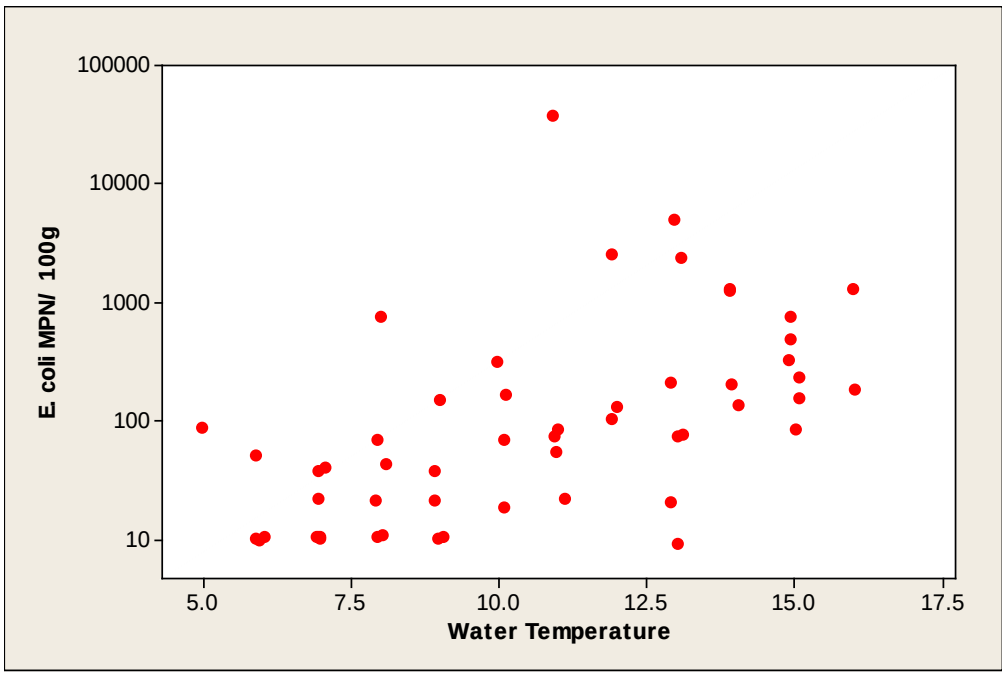

Figure 11.9 Scatterplot of result by water temperature

A statistically significant positive correlation was found between *E. coli* samples and water temperature (Spearmans rank correlation = 0.664, p<0.001). Fewer low results occurred as water temperature increased and no high results were found at temperatures below 8°C. Highest results occurred at temperatures above 11°C.

11.6.4 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence, and hence freshwater-borne contamination at the site. Figure 11.8 presents a scatter plot of *E. coli* result against salinity.

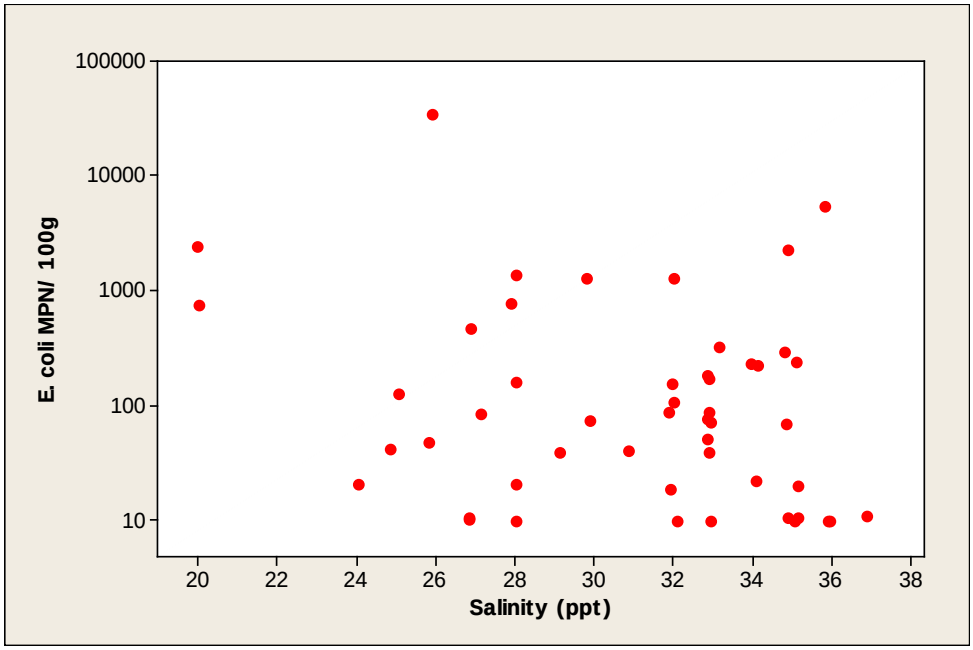

Figure 11.10 Scatterplot of result by salinity

No statistically significant correlation was found between the *E. coli* result and salinity (Spearman's rank correlation= -0.192, p=0.181). However, a higher number of very low results occurred at higher salinity and no very low results occurred at salinity below 24 ppt, though only two samples were recorded below this salinity level.

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

Seven of the 54 samples gave a result of over 1000 MPN/ 100 g, details of which are presented in table 11.2.

Table 11.2 Historic *E. coli* sampling results over 1000 *E. coli* MPN/100 g

Collection date	*E. coli* (MPN/100 g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tidal state (high/low)	Tidal state (spring/neap)
05/08/2008	1300	NM 70756 27338	0.8	115.5	14	32	Ebb	Decreasing tides
06/10/2009	2400	NM 70759 27339	23.4	50.9	12	20	Low	Springs
13/07/2010	1300	NM 70757 27335	4.0	75.5	14	30	Ebb	Springs
10/08/2010	1300	NM 70757 27340	27.6	35.5	16	28	Low	Increasing tides
05/10/2010	2400	NM 70760 27330	24.2	64.1	13	35	Ebb	Increasing tides
05/07/2011	5400	NM 70758 27331	*	*	13	36	Ebb	Decreasing tides
25/10/2011	36000	NM 70758 27337	*	*	11	26	Low	Increasing tides

* Data unavailable

Results were associated with a range of rainfall, water temperature and salinity values with no clear trends between them. Due to the intertidal nature of the fishery, sampling at this location tends to occur on only part of the tidal cycle (Figures 11.7 and 11.8).

11.8 Summary and conclusions

Most of the samples were taken from within a very limited area located along the western side of the oyster farm. No clear spatial variation in results was apparent within the area sampled. No samples were taken from the eastern side of the oyster farm.

Historial monitoring results have shown intermittently very high levels of faecal contamination. Two samples, both taken in 2011, exceded 4600 *E. coli* MPN/100 g. The overall trend in results over the period 2007-2011 suggests a slight increase in contamination levels over that time, largely driven by a relatively small number of results exceeding 1000 *E. coli* MPN/100 g.

There was a strong seasonal trend in monitoring results, with results greater than 230 *E. coli* MPN/100 g occurring from June to December and peak results occurring in July and October. Results were lowest in February and March. A statistically significant difference was found between results by season, with results in summer and autumn higher than in winter and spring.

A positive correlation was found between results and rainfall during the period prior to sampling. This relationship was stronger with 2-day rainfall than with 7-day rainfall, though both were statistically significant. However, very high results occurred at very low rainfall levels and the absence of very low results at moderate to high rainfall may have been responsible for the correlation.

There was no statistically significant association between tidal cycle and *E. coli* results. Samples tended to be taken during low, spring tides due to the intertidal nature of the fishery.

A significant positive correlation was found between results and sea water temperature and no correlation was found between results and salinity.

Results greater than 1000 *E. coli* MPN/100 g occurred in only three months: July, August and October. A wide range of rainfall and salinity values were recorded for these samples, however recorded water temperature was 11°C or above for all of them. All were taken on a low or ebbing tide and around spring tides, the large majority of samples from this site were taken under these conditions and therefore no conclusions can be drawn with regard to the effect of tidal state on *E. coli* results.

11.9 Sampling frequency

When a production area holds a non-seasonal classification and the geometric mean of the results falls within a certain range, the EURL Good Practice Guide (GPG) recommends that consideration be given to the sampling frequency being decreased from monthly to bimonthly. The recommendations are based on regular sampling having taken place and an initial three year data set of 24 results. As the area currently holds a seasonal classification an assessment was not undertaken.

12. Designated Shellfish Growing Waters Data

The western end of the Loch Spelve Croggan Pier production area lies within the Loch Spelve designated shellfish growing water. The area was designated under the European Community Shellfish Waters Directive (2006/113/EC) in 1998. Under the Shellfish Waters Directive (European Communities, 2006), designated waters must be monitored quarterly for faecal coliforms in the shellfish flesh and intervalvular fluid. SEPA is responsible for ensuring that this monitoring is undertaken, and have used shore mussels for this purpose.

Results of shellfish monitoring to 2007 were provided by SEPA and are presented in Table 12.1. The relative positions of the SGW boundary, the Loch Spelve Croggan Pier production area, and the SGW monitoring points are shown in Figure 12.1.

Table 12.1 SGW monitoring Loch Spelve, Croggan Pier

Year	Quarter	Faecal coliform results (FC/100 g)
		NM 70324 27431
1999	Q3	1100
	Q4	2200
2000	Q1	110
	Q2	>18000
	Q3	70
	Q4	220
2001	Q1	<20
	Q2	<20
	Q3	220
	Q4	70
2002	Q1	40
	Q2	220
	Q3	20
	Q4	<20
2003	Q1	<20
	Q2	-
	Q3	310
	Q4	20
2004	Q1	90
	Q2	110
	Q3	2400
	Q4	110
2005	Q1	430
	Q2	500
	Q3	430
	Q4	70
2006	Q1	40
	Q2	>18000
	Q3	160000
	Q4	70
2007	Q1	40

- No result reported

Mussel samples were taken for faecal coliform analysis from three points within the growing waters. The Loch Spelve Camas and Loch Spelve Fish Farm monitoring points are located on the south western shore of the main water body of Loch Spelve and are not likely to be representative of water quality conditions at the Croggan Pier, therefore they are not considered here.

Since 2007, SEPA have obtained shellfish classification monitoring results (*E. coli*) under an agreement with FSAS for the purposes of SGW monitoring. Any results utilised from the Croggan Pier production area will already have been considered previously in this report.

The geometric mean result for samples taken from the Loch Spelve Croggan Pier monitoring point is 200 FC/100 g. Although the majority of results were <230 FC/100 g, indicating overall low levels of faecal contamination, there were episodic results between 1000 and 160000 FC/100 g, indicating high to exceptionally high levels of contamination at the time of sampling. Highest results occurred in calendar Q2 and Q3, which equates to the period April to September. Sampling dates were not provided and therefore it is not possible to identify whether this corresponded with the seasonal variation seen in shellfish hygiene monitoring results.

Although levels of faecal coliforms are usually correlated to levels of *E. coli* at a ratio of roughly 1:1, the ratio depends on a number of factors, such as environmental conditions and the source of contamination. Comparison is further complicated by differences in accumulation between the different bivalve species. Consequently, the results present in Table 12.1 are not directly comparable with the other shellfish testing results presented in this report.

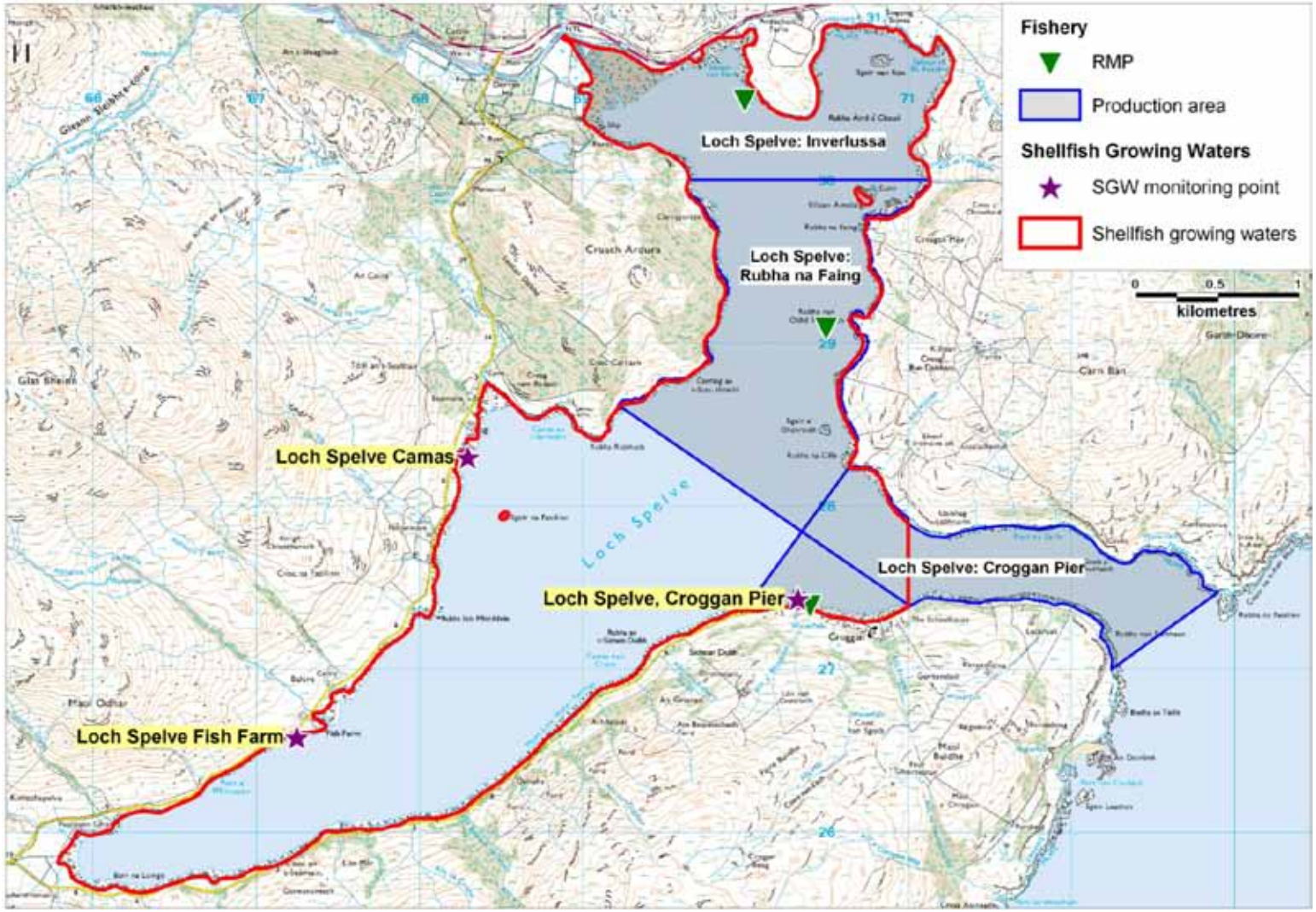

Figure 12.1 Designated shellfish growing water – Loch Spelve

13. River Flow

There are no river gauging stations on rivers or burns within Loch Spelve. The rivers and streams listed in Table 13.1 were measured and sampled during the shoreline survey. These represent the potential freshwater inputs to the loch in the vicinity of the Loch Spelve Croggan Pier fishery. There was no rain on the day of the shoreline survey. The locations, together with the calculated loadings, are shown in Figure 13.2. Where the bacterial loading is labelled on the map, the scientific notation is written in digital format, as this is the only format recognised by the mapping software. So, where normal scientific notation for 1000 is 1×10^3, in digital format it is written as 1E+3.

Table 13.1 Watercourse loadings for Loch Spelve: Croggan Pier

No	Grid Ref	Description	Width (m)	Depth (m)	Flow (m/s)	Flow in m^3/day	*E. coli* (cfu/ 100 ml)	Loading (*E. coli* per day)
1	NM 71415 27384	Stream	Too small to measure or sample*					
2	NM 71469 27401	Stream	Too small to measure or sample*					
3	NM 71499 27404	Pond with outflow	Too small to measure or sample*					
4	NM 71528 27392	Stream	Too small to measure or sample*					
5	NM 71854 27392	Stream	1.3	0.09	0.037	374	<100	$<3.7 \times 10^8$
6	NM 71957 27362	Ditch, water ponded with aquatic flora present	Too small to measure or sample*					
7	NM 70848 27295	Allt Frogach	0.17	0.03	0.436	192	1200	2.3×10^9
8	NM 70526 27306	Stream	0.54	0.07	0.343	1120	<100	$<1.1 \times 10^9$
9	NM 70119 27350	Stream	Too small to measure or sample*					
10	NM 70306 27373	Culverted stream (Allt à Bhodaich)	Piped flow not suitable for flow meter			259**	<100	$<2.6 \times 10^8$

*Insufficient flow at time of survey
**Flow estimated using bucket – 15 litre volume, average fill time 5 seconds

Most of the watercourses observed during the shoreline survey were not flowing sufficiently to measure or sample. Only one watercourse, Allt Frogach, located <50 m south east of the fishery, yielded an *E. coli* result indicating marked faecal contamination (1200 *E. coli* cfu/100 ml). Allt Frogach also had the highest calculated loading of 2.3×10^9 *E. coli* cfu/100 ml per day. Loadings in the streams would be expected to increase significantly after rainfall.

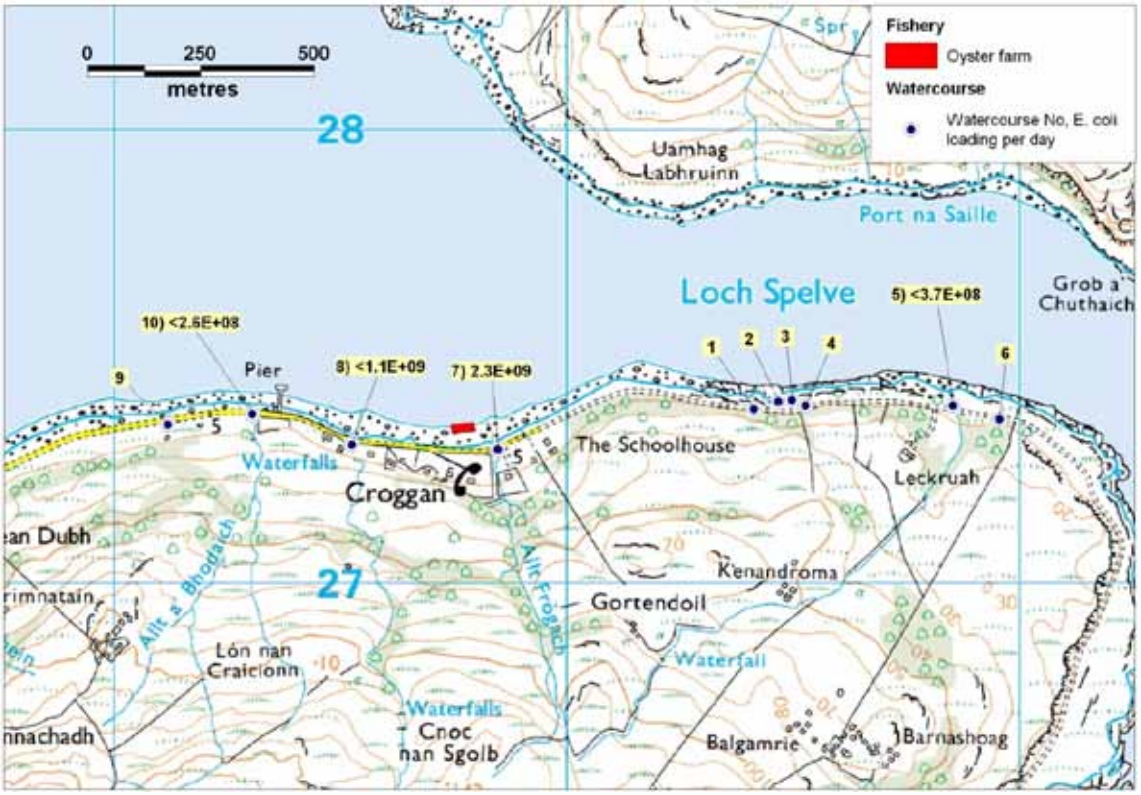

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Figure 13.1 Map of watercourse loadings at Loch Spelve: Croggan Pier

Allt Frogach is the watercourse that will contribute most to the *E. coli* contamination in the vicinity of the fishery. Other watercourses may have some impact after heavy rainfall. During heavy rainfall, direct run-off from the southern shore may carry faecal contamination from animal droppings into the sea near to the oyster farm.

14. Bathymetry and Hydrodynamics

The bathymetry for Loch Spelve is shown in Figure 14.1. The loch lies on the eastern side of the island of Mull. The mouth of the loch is narrow (approximately 400 m wide) and shallow and lies west to east. The maximum depth shown within the channel is 8.3 m although there is a deep gulley actually at the mouth and this reaches almost 20 m. The main part of the loch lies at the western end of that channel with the southern part (approximately 4.5 km long) running to the south west and the northern part (approximately 2.5 km long) lying approximately north.

The oyster farm is located at the edge of an intertidal area that lies on the southern shore at the junction of the inner channel at the loch mouth and the southern arm of the main loch. Depths immediately off the oyster farm are less than 2 m. Further offshore, there is a marked difference in depth to the east, where the shallower channel lies towards the mouth, approximately 5 m in depth, and the main loch basin to the west which shelves steeply to more than 20 m.

14.1 Tidal Curve and Description

The two tidal curves shown in Figure 14.2 are for Oban, approximately 13.5km from Loch Spelve. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 BST on 31/08/11 and the second is for seven days beginning 00.00 BST on 07/09/11. This two-week period covers the date of the shoreline survey. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle.

The following is the summary description for Oban from TotalTide:

0372 OBAN is a Standard Harmonic port.
The tide type is Semi-Diurnal.

HAT	4.5 m
MHWS	4.0 m
MHWN	2.9 m
MSL	2.39 m
MLWN	1.8 m
MLWS	0.7 m
LAT	0.0 m

Predicted heights are in metres above chart datum. The average tidal range at spring tidies 3.3 m and at neap tide 1.1 m. The area is therefore mesotidal (moderate tidal range).

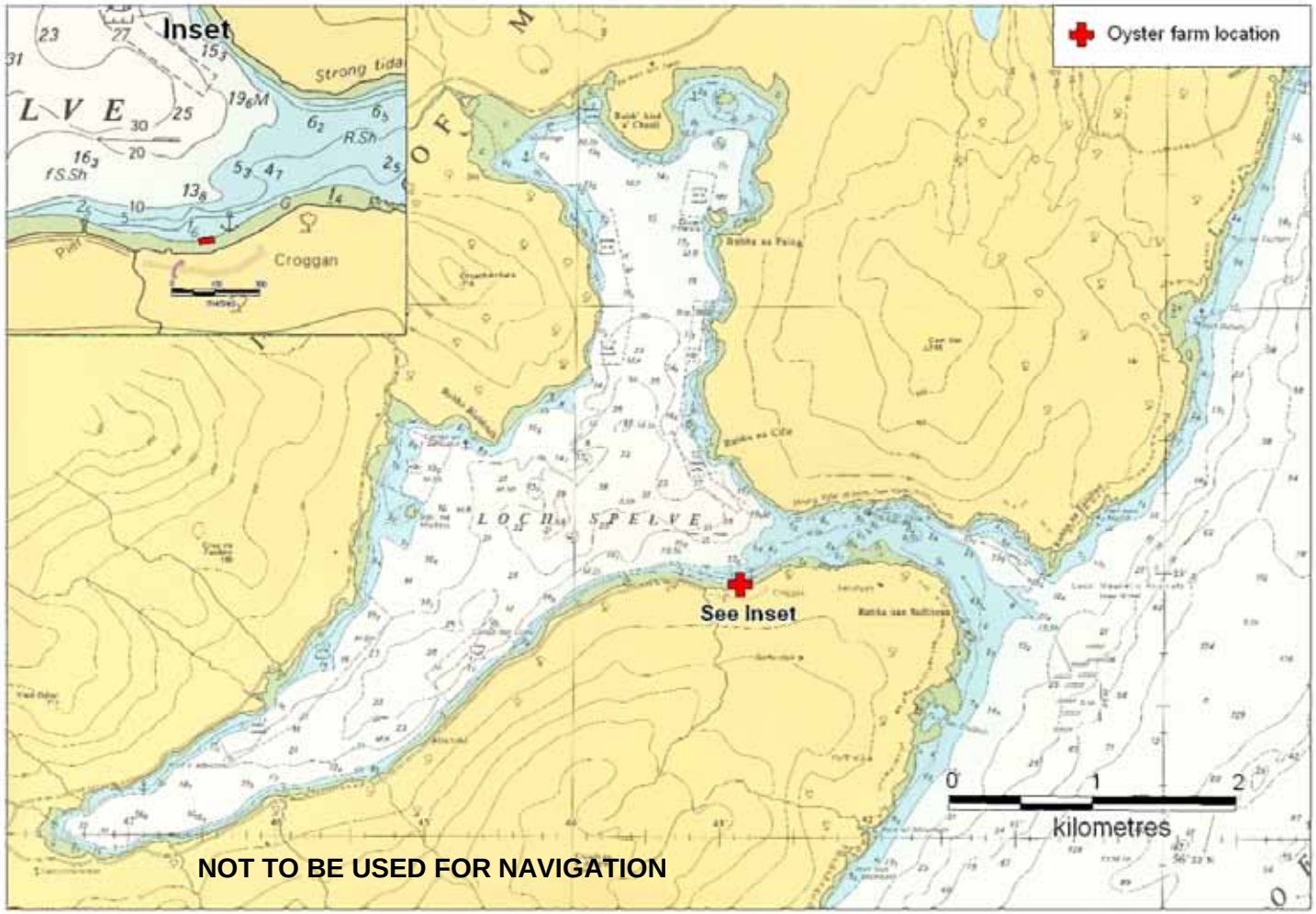

Figure 14.1 Bathymetry at Loch Spelve

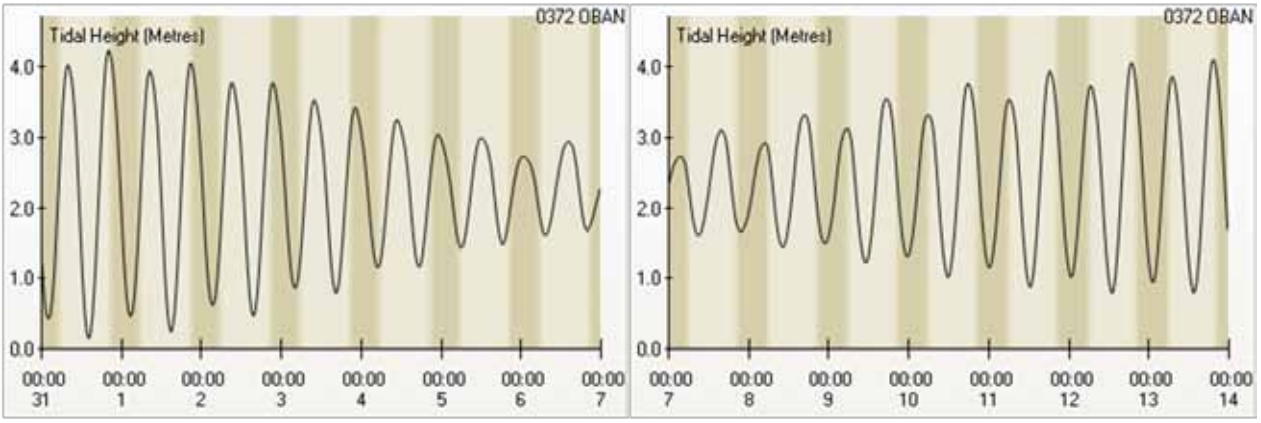

Figure 14.2 Tidal curves for Oban

14.2 Currents

There are no tidal diamonds within Loch Spelve itself. However, the UKHO Chart shows the flood tide off the oyster farm flowing directly west. No estimate of rate is given. SEPA provided data from a current meter study that had been undertaken at a site south-west of the oyster farm. Summary information on the site is given in Table 14.1 and the position is shown on the map in Figure 14.3. Plots of the current directions and speeds, together with the wind direction and speeds over the relevant period, are shown in Figure 14.4.

Figure 14.3 Current meter location

Table 14.1 Survey period for the current meter study

Location	NGR	Survey period
Dalnaha	NM 68825 26911	20/10/2007 – 04/11/2007

The current direction near the sea bed is essentially unimodal, flowing towards the north-east over the study period. The directions at mid-depth and near-surface are strongly bimodal, flowing towards the north-east and south-west. The north-easterly currents predominated and tended to be stronger. The change between unimodal and bimodal with depth cannot have been influenced by the wind direction as this was predominantly from the south and south-west during the period of the survey (and thus would have driven surface currents in the same direction as those seen at depth). However, the wind could have affected the magnitude of the current seen at the surface. The current directions are generally parallel to the shore at that point.

Median and maximum current speeds at the three depths are shown in Table 14.2.

Table 14.2 Median and maximum current speeds

Depth	Current speed (cm/s)	
	Median	Maximum
Near-bottom	4.0	19.8
Mid-depth	2.7	17.8
Near-surface	3.6	25.7

Currents in Loch Spelve are generally low. The highest current speeds were seen at the surface. At a maximum current speed of 26 cm/s (0.26 m/s; 0.51 knots), contamination would be expected to be carried a maximum of approximately 3.7 km over a flood or ebb tide, ignoring any effects of dilution or dispersion. Most of the time, currents would be markedly lower than this and the transport distances would therefore be correspondingly less.

At the oyster fishery, the current would also be expected to flow parallel to the shore, as indicated by the UKHO chart. Given that the oyster farm is located near to the narrows at the mouth of the loch, current speeds may be greater than those observed at the current meter location. The Scottish Sea Lochs Catalogue gives an estimated flushing time of 3 days, which is moderate (Edwards & Sharples, 1991).

14.3 Salinity

The Scottish Sea Lochs Catalogue gives a calculated salinity reduction of 0.3 ppt for Loch Spelve (Edwards & Sharples, 1991). This indicates a general low influence of fresh water across the loch as a whole. However, the reduction in salinity could be expected to be greater near to freshwater sources. Salinity results are given in the shoreline survey report for three spot samples taken along the shore of the loch, including one taken at the shellfishery itself. These gave results ranging from 33.6 to 34.9 ppt, indicating little freshwater influence. Density driven currents are not expected to be occur.

14.4 Conclusions

Much of Loch Spelve is deep and this will mean that contamination will be subject to significant dilution away from shore. However, such dilution will be much less for contamination from sources in the near vicinity of the oyster farm.

Currents within the loch are generally low but will be low to moderate in the vicinity of the oyster farm, due to its location near to the narrows at the mouth of the loch. The currents at the farm will tend to flow to the west on the incoming tide and to the east on the outgoing tide. Impact from local sources of cotnamaintion will predominate. The surface water in the vicinity of the famr will be protected from southerly or south-westerly winds due to the location, but such winds could enhance the effect of ebb tides and reduce the effect of flood tides on the transport of contaminants at that site.

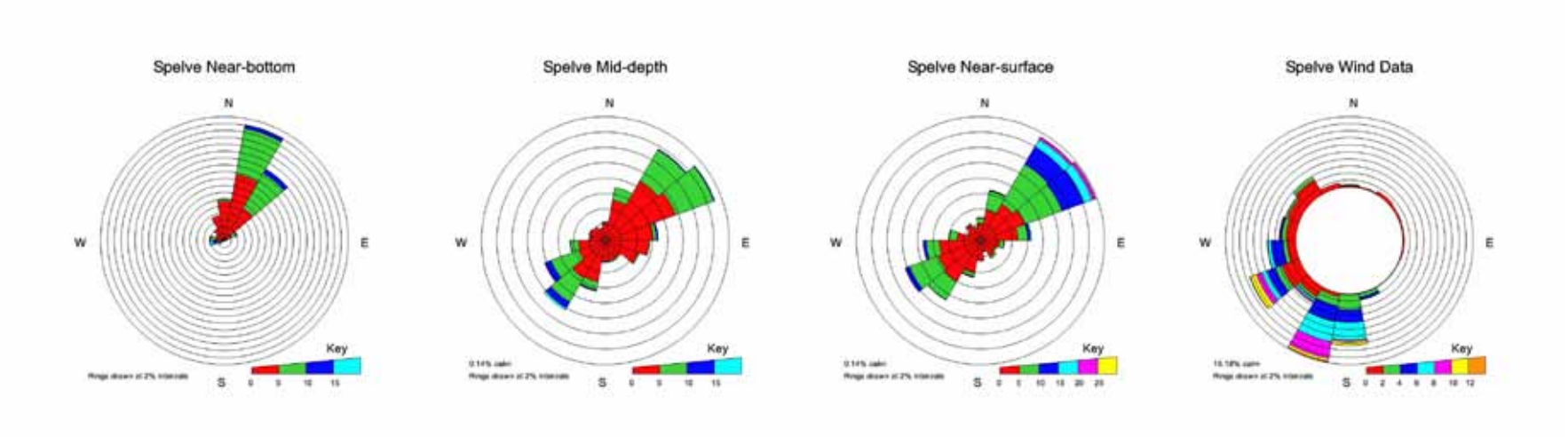

Figure 14.4 Current and wind plots for the Dalnaha current meter study

Currents measured in cm/s. Wind measured in m/s. As per convention, currents are plotted against the direction towards which they are travelling while winds are plotted against the direction from which they are travelling. The length of each segment in a plot relates to the proportion of observations lying in that direction. The speed relates to the colour key beneath each plot. The proportion that each colour takes up in an individual segment relates to the proportion of observations in that direction having speed in that range. Directions are in degrees magnetic.

15. Shoreline Survey Overview

The shoreline survey was conducted on the 31st August 2011 under overcast, but dry and calm conditions. At the time of the survey the tide was dropping with strong tidal flows observed west to east.

Pacific oysters were grown in mesh bags laid on 6 raised, perforated steel beds between rock groynes on the intertidal shoreline east of Croggan Pier. The racks and bags are pressure washed periodically to keep seaweed, sea squirts and other growth from adhering to the bags and interfering with water flow. Likewise the seabed in the small embayment is kept clear to allow unimpeded flow of water around the site. Harvesting may occur at any time of year, in accordance with demand. The farm may be expanded deeper into the loch in the future.

Seven homes line the southern shoreline adjacent to the fishery. Only three of these are reported to be permanently occupied, with the remainder used as holiday lets. The harvester, who lives in one of the homes, reported that there is no mains sewerage provision to the area and that the homes are all on individual septic systems as far as they are aware. Two septic tanks were observed, and one discharge through a culvert under the road that appeared to have septic content. No pipes were observed to discharge directly to the shore. The tank observed at the farmhouse east of the fishery had a perforated pipe leading from the tank to underground, and is presumed to be on soakaway. No odour was detected and the house appeared to be unoccupied.

Croggan Pier, to the west of the oyster farm, was found to be disused.

A large number of sheep were present on the shoreline adjacent to the fishery during the survey. Cattle droppings were also seen along the shoreline, though no cattle were seen. The sampling officer identified that cattle were occasionally present on the shore adjacent to the fishery.

A small pontoon jetty was positioned at the shoreline west of the fishery. This was used by 2 small open boats during the survey. In addition, two sailing yachts were observed, one passing out of the loch and one waiting outside the entrance for the tide to turn. Apart from the small number of houses the land to the south of the fishery was used for grazing. Land on the north shore opposite the fishery was steeply sloped and covered with rough grassland, bracken and small areas of deciduous woodland. Two people were observed breaking camp near the mouth of the loch on the north shore.

An otter latrine and large male otter were observed near the shore east of the fishery during the survey. A group of 9 gulls were observed at the west end of the fishery. No other groups of birds or other animals were observed.

Small watercourses were distributed along the south shoreline, as well as some ditches which drained water away from pastures around the houses.

Those actively flowing at the time of survey were recorded, measured and sampled. All others were recorded only.

Water samples taken in close vicinity to the fishery mostly contained little *E. coli* (<100 cfu/100 ml) except for one freshwater sample which had a result of 1200 *E. coli* cfu/100 ml, which indicated some faecal contamination. A sample was also taken from a presumed septic pipe; this had a result of 2000 *E. coli* cfu/100 ml. Seawater samples taken from east of the oyster farm were found to contain greater concentrations of *E. coli* than that taken to the east of the oyster farm. The seawater sample taken at the oyster farm contained no detectable *E. coli*. At the time of sampling the tide was flowing strongly from west to east. One oyster sample was taken which gave a low *E. coli* result of 20 MPN/100 g.

Figure 15.1 shows a summary map of the most significant findings from the shoreline survey.

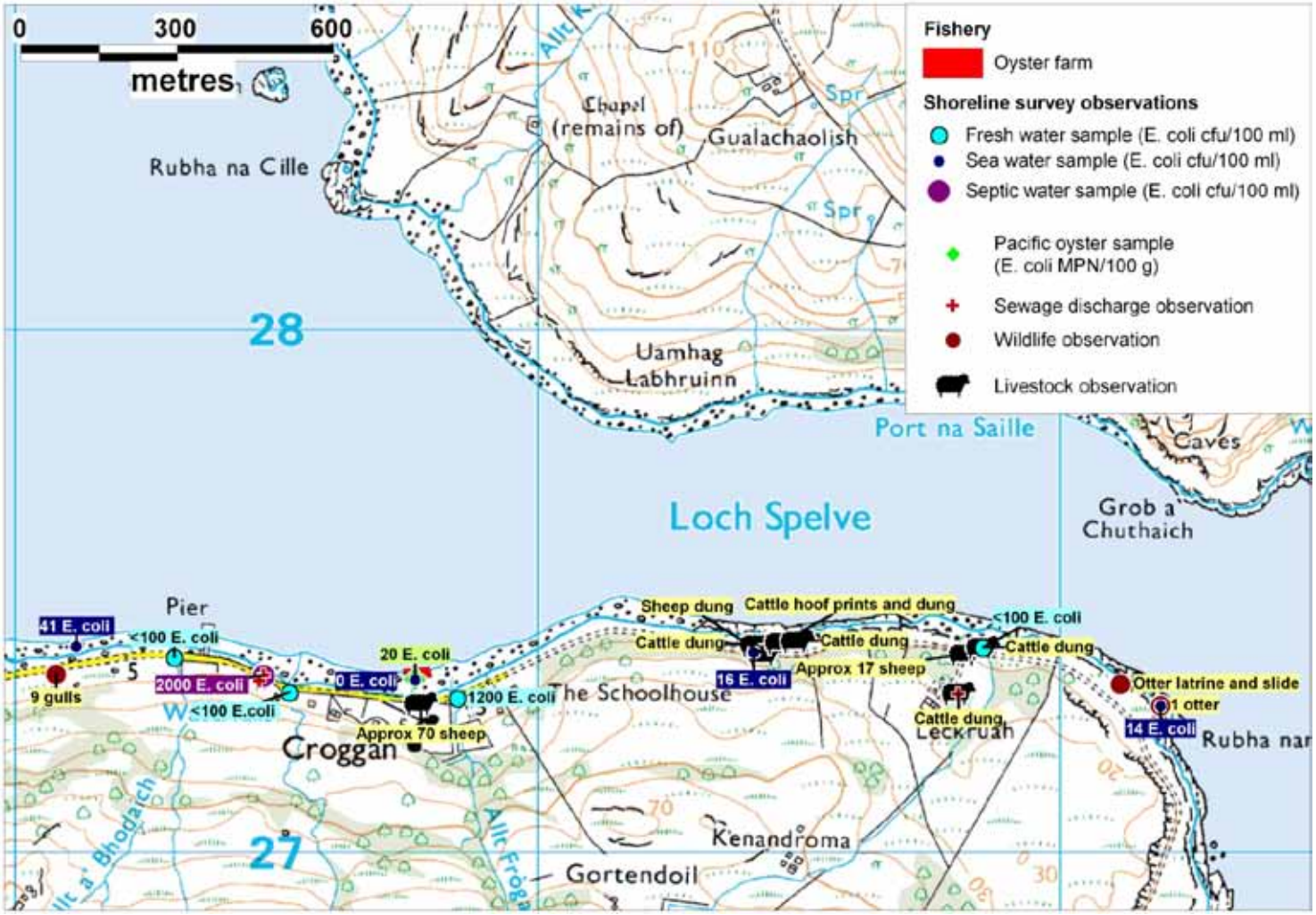

Figure 15.1 Summary of shoreline survey findings for Loch Spelve: Croggan Pier

16. Overall Assessment

Human sewage impacts

Although the human population for the area is very small, the oyster farm is located adjacent to seven dwellings, three of which are in permanent occupation with the remainder used as holiday lets. One septic tank discharged to a ditch and then to the sea via a culverted 270 m west of the oyster farm. A water sample taken from the culvert outflow showed significant faecal content. The only discharge consent reported for the area pertained to a septic tank near the Allt Frogach, which was found to carry significant faecal contamination. It is not clear whether the soakaway system was contributing to the contamination levels observed. The consent location plots within 30 m of the Allt Fròg ach, but the location of the soakaway field itself was not identified.

Soil types identified along the south shore of the loch, in the vicinity of the homes at Croggan, were classed as freely draining and therefore septic tank soakaways kept in good order would not be expected to significantly affect water quality at the fishery. The condition of the septic tanks in the area is not known. The majority are not registered with SEPA, and therefore may be quite old. If any of these is malfunctioning, it could lead to higher levels of contamination at the oyster farm when the septic tanks are in use.

Yachts anchoring off the shore near the fishery are likely to significantly impact water quality at the oyster farm when they are present, as they may discharge septic waste overboard very near the fishery.

Any impact from human sewage would be likely to be higher during the summer holiday periods when more of the homes may be occupied and there is more yachting and cruising activity. The majority of homes lie to the west of the oyster farm, though the stream passing one of the septic tanks lies to the east of the oyster farm. There is insufficient information known about the discharges to assess whether contamination potentially arising on one side of the fishery would predominate over that arising on the other.

Agricultural impacts

Agricultural impacts at the fishery are significant. A large number of sheep were present on the shoreline south of the oyster farm during the survey. Even though these animals had only been present for a day, there were large numbers of droppings along the shore. According to the harvester, sheep are only brought down to the pastures along the Croggan shoreline a few times a year and most of the time are grazed further afield.

Cattle dung was seen along the shore, and cattle were reportedly present on the shoreline immediately adjacent to the oyster farm from time to time. The harvester does attempt to keep the cattle away from the oyster farm, moving them on when they are found at the shore.

Due to the numbers of animals and faecal material seen in close proximity to the fishery, faecal contamination from livestock sources is likely to be a significant contributor to *E. coli* levels found at the fishery. Sources likely to predominate are the Allt Frogach, immediately to the east of the oyster farm and any direct deposition to the shoreline south of the oyster farm.

Wildlife impacts

Wildlife species are likely to contribute to background levels of contamination at the fishery, however it is not possible to estimate their impact due to the limited information available on their numbers and distribution. Seals and birds may either directly deposit faecal material in the vicinity of the oyster farm, or deposit them on shoreline areas where they are later washed into the loch by the tide. Impacts from deer and otters are most likely to be carried via fresh water sources to the waters of the fishery. It is likely that these animals contribute to background levels of contamination found throughout the loch, however there is no specific evidence to suggest any one part of the oyster farm is more likely to be affected than another.

Seasonal variation

Seasonal variation was observed in historical monitoring results, with *E. coli* result significantly higher in summer and autumn than in winter and spring. This variation may be due to changes in seawater temperature, which generally peaks in September and is lowest in March and a significant correlation was found between monitoring results and seawater temperature. However, this may also be due to seasonal variation in faecal sources and in rainfall.

Seasonal increases are expected in human population, with more of the local homes in occupation during holiday periods and visiting yachts more likely to be present at the anchorage. The peak period for these uses would be from July and August, however there may also be another peak during the Christmas holidays, particularly for the holiday homes.

A larger number of livestock are likely to be present in the area from roughly April to September when lambs, and possibly calves, are present. At the time of shoreline survey in late August, lambs were being separated from the ewes for shipment to market. According to the harvester, sheep are only brought down to the pastures along the Croggan shoreline a few times a year and most of the time are grazed further afield.

Rainfall increased from August onward and was highest in November and January. Weather was drier from February to July. Taking the above into account, it would be expected that rainfall run-off would increase during the autumn and winter months causing a significant contribution to faecal contamination of the production area. However, it is likely that associated faecal contamination entering the production area will be greatest when

extreme rainfall events occur during summer or early autumn after a build-up of faecal matter on pastures during the drier summer months.

Rivers and streams

A number of small streams discharge along the south shore in the vicinity of the oyster farm. Significant faecal loadings were calculated for Allt Frogach, 50 m east of the oyster farm and small outlet located 230 m west of the oyster farm. It is suspected that both may carry human faecal contamination in addition to other diffuse sources. Loadings observed in the streams were found during relatively dry conditions and would be expected to increase significantly after rainfall.

Allt Frogach is located closest to the oyster farm, and is expected to contribute most to the *E. coli* contamination in the vicinity of the fishery. Other watercourses may have some impact after heavy rainfall. During heavy rainfall, overland flow from the southern shore may carry faecal contamination from animal droppings into the sea near to the oyster farm.

Movement of contaminants

Although much of Loch Spelve is deep and there will be significant dilution of contaminants away from shore, there will be much less dilution of contaminants arising from sources in the near vicinity of the oyster farm where depths are shallow.

Currents in the vicinity of the oyster farm are expected to be low to moderate due to its location near to the narrows at the mouth of the loch and will tend to flow to the west on the incoming tide and to the east on the outgoing tide.

The surface water in the vicinity of the farm will be protected from southerly or south-westerly winds due to the location, but such winds could enhance the effect of ebb tides and reduce the effect of flood tides on the transport of contaminants at that site.

Contamination carried via Allt Frogach is likely to be drawn westward across the oyster farm by the flood tide and then taken back eastward on the ebb, while contamination arising from the ditch outflow west of the fishery would do the opposite. Both sources are expected to affect water quality throughout the farm.

Faecal material deposited by livestock at the shoreline would be picked up off the shore at high tide, or carried to the sea via rainfall runoff, and would be carried across the oyster farm on the ebb tide and brought back in on the flood tide.

Temporal and geographical patterns of sampling results

The large majority of samples were taken from a small area along the western side of the oyster farm, therefore geographical assessment of variation was

not possible. An oyster sample was taken during the shoreline survey from a point east of the monitoring samples, though still near the centre shoreline edge of the farm and this was found to be very lightly contaminated. Results of Shellfish Waters Directive monitoring at Croggan Pier showed periodically extremely high levels of contamination at the pier up to 2007, suggesting highly significant sources in the vicinity. However, as the pier has been disused for many years, the source of such high contamination levels is unclear. Highest results occurred in the 2nd and 3rd quarters, or April to September, however it is not possible to identify whether this corresponded with the seasonal variation seen in shellfish hygiene monitoring results.

The trendline in Figure 11.2 suggests a slight increase in results over the time period studied, with peak results increasing over the years.

Conclusions

The oyster fishery at Loch Spelve: Croggan Pier appears to be subject to periodic, and significant, episodes of faecal contamination. These appear to be more likely to occur between June and December, with results exceeding 1000 *E. coli* MPN/100 g occurring in July, August and December. These correspond with peak holiday periods, though it is not known whether other factors, such as livestock movements, may also coincide with this season.

The principal potential sources of contamination identified in the survey are sewage discharges associated with the properties on the shore adjacent to the oyster farm and diffuse agricultural pollution from livestock droppings deposited at or near the shoreline. Potential sources lie both to the west and east of the oyster farm. However, the Allt Frogach lies very close to the east end of the farm and carries relatively high levels of diffuse faecal pollution.

The harvester tends the oyster racks carefully, using a pressure washer to remove algae and seasquirts in order to promote better water circulation around the oysters. It may be that this would also serve to increase uptake of contaminants, however it is not clear whether this would be a significant driver of faecal contamination levels in the oysters.

The current production area boundaries overlap those of the Loch Spelve: Rubha na Faing production area, and should be amended to eliminate this.

17. Recommendations

Production area

It is recommended that the production area boundaries be amended to eliminate areas contained within the Loch Spelve: Rubha na Faing production area. Due to the location and nature of the fishery, it is not possible to exclude potential polluting sources from the production area. The recommended area is described as the area bounded by lines drawn between NM 7039 2738 and NM 7039 2781 and between NM 7039 2781 and NM 7100 2739 and extending to MHWS.

RMP

As the eastern end of the oyster farm has not historically been monitored, and it lies nearer to the Allt Frogach and the anchorage, it is recommended that the monitoring point be amended to the eastern side of the farm in order to build a picture of contaminant levels at that side of the fishery. Therefore the recommended RMP is NM 7078 2734.

Depth of sampling

Not applicable

Tolerance

A standard sampling tolerance of 20 metres is recommended due to the size of the operation.

Frequency

As the area currently holds a seasonal classification it is recommended that monthly monitoring be continued.

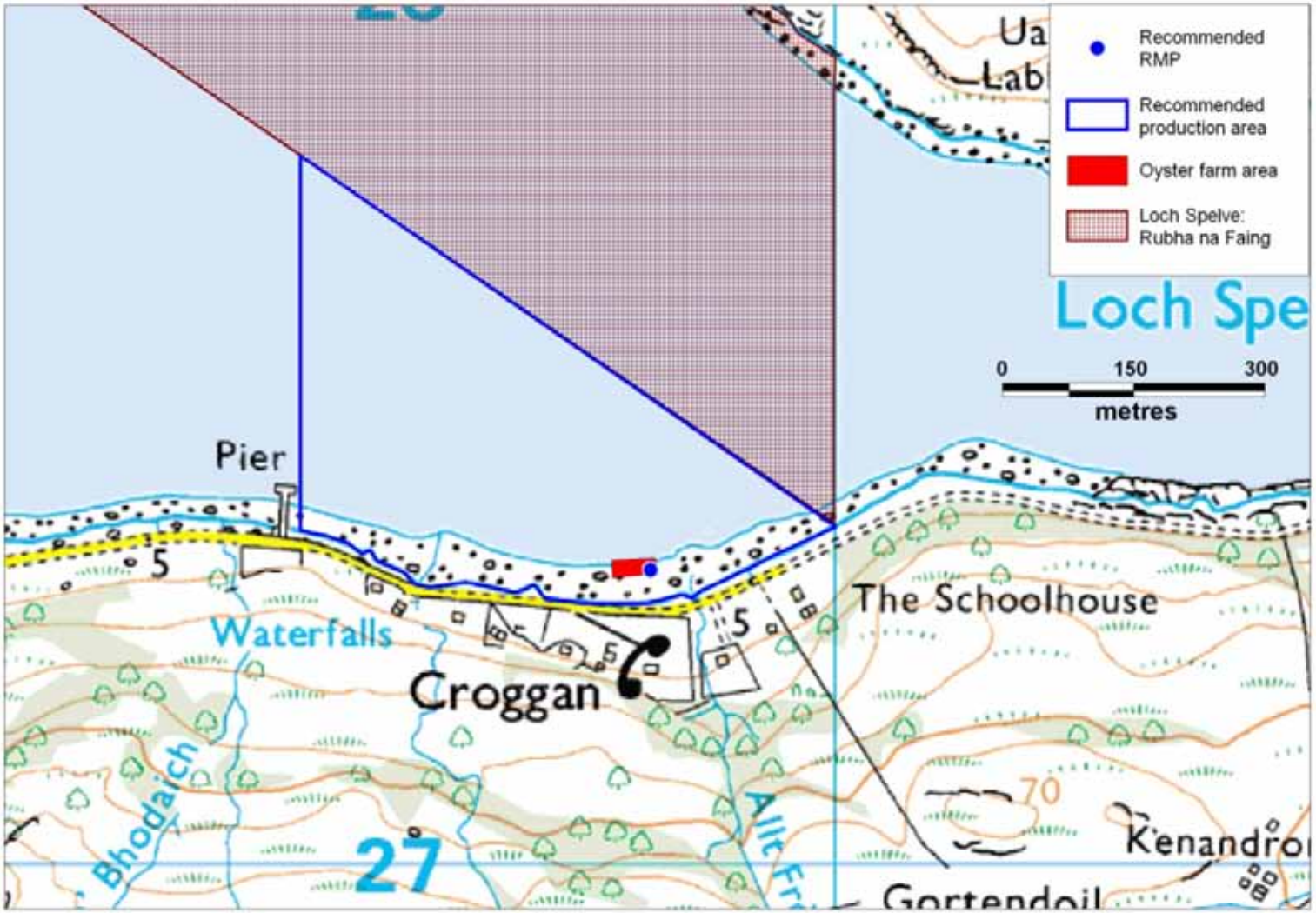

Figure 17.1 Map of recommendations at Loch Spelve – Croggan Pier

18. References

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

Clyde Cruising Club (2007). Sailing Directions and Achorages – Part 2, Kintyre to Ardnamurchan. Clyde Cruising Club Publications Ltd., Glasgow.

European Communities (2006). Directive 2006/113/EC of the European Parliament and of the Council of 12 December 2006 on the quality required of shellfish waters (codified version). *Off. J. Eur. Communities*, L 376, 27.12.2006, 14-20.

EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas (2010). Microbiological monitoring of bivalve mollusc harvesting areas, guide to good practice: technical application. Cefas - European Union Reference Laboratory for monitoring bacteriological and viral contamination of bivalve molluscs. Issue 4.

Kay, D, Crowther, J., Stapleton, C.M., Wyler, M.D., Fewtrell, L., Anthony, S.G., Bradford, M., Edwards, A., Francis, C.A., Hopkins, M. Kay, C., McDonald, A.T., Watkins, J., Wilkinson, J. (2008). Faecal indicator organism concentrations and catchment export coefficients in the UK. *Water Research* 42, 442-454.

Lee, R.J., Morgan, O.C. (2003). Environmental factors influencing the microbial contamination of commercially harvested shellfish. *Water Science and Technology* 47, 65-70.

Mallin, M.A., Ensign, S.H., McIver, M.R., Shank, G.C., Fowler, P.K. (2001). Demographic, landscape, and meteorological factors controlling the microbial pollution of coastal waters. *Hydrobiologia* 460, 185-193.

Mitchell, C., Griffin, L., Trinder, M. & Newth, J. (2010). The population size of breedinggreylag geese *Anser anser* in Scotland in 2008/09. *Scottish Natural Heritage Commissioned Report No. 371*

Sea Mammal Research Unit (2002). Surveys of harbour (common) seals in Shetland and Orkney, August 2001. *Scottish Natural Heritage Commissioned Report F01AA41.*

Spellman, A. (2012). Isle of Mull Bird Report and Species List, Issue 9. http://www.mullbirds.com.

Surveys of harbour seals on the west and east coasts of Scotland. Report No: F00PA41 (2001) Sea Mammal Research Unit, St Andrews University

19. List of Figures and Tables

Appendices

1. **Geology and Soils Assessment Method**
2. **General Information on Wildlife Impacts**
3. **Tables of Typical Faecal Bacteria Concentrations**
4. **Statistical Data**
5. **Hydrographic Methods**
6. **Shoreline Survey Report**

Geology and Soils Assessment Method

Component soils and their associations were identified using uncoloured soil maps (scale 1:50,000) obtained from the Macaulay Institute. The relevant soils associations and component soils were then investigated to establish basic characteristics. From the maps seven main soil types were identified: 1) humus-iron podzols, 2) brown forest soils, 3) calcareous regosols, brown calcareous regosols, calcareous gleys, 4) peaty gleys, podzols, rankers, 5) non-calcareous gleys, peaty gleys: some humic gleys, peat, 6) organic soils and 7) alluvial soils.

Humus-iron podzols are generally infertile and physically limiting soils for productive use. In terms of drainage, depending on the related soil association they generally have a low surface % runoff, of between 14.5 – 48.4%, indicating that they are generally freely draining.

Brown forest soils are characteristically well drained with their occurrence being restricted to warmer drier climates, and under natural conditions they often form beneath broadleaf woodland. With a very low surface % runoff of between 2 – 29.2%, brown forest soils can be categorised as freely draining (Macaulay Institute, 2007).

Calcareous regosols, brown regosols and calcareous gleys are all characteristically freely draining soils containing free calcium carbonate within their profiles. These soil types have a very low surface % runoff at 14.5%.

Peaty gleys, peaty podzols and peaty rankers contribute to a large percentage of the soil composition of Scotland. They are all characteristically acidic, nutrient deficient and poorly draining. They have a very high surface % runoff of between 48.4 – 60%.

Non-calcareous gleys, peaty gleys and humic gleys are generally developed under conditions of intermittent or permanent water logging. In Scotland, non-calcareous gleys within the Arkaig association are most common and have an average surface % runoff of 48.4%, indicating that they are generally poorly draining.

Organic soils often referred to as peat deposits and are composed of greater than 60% organic matter. Organic soils have a surface % runoff of 25.3% and although low, due to their water logged nature, results in them being poorly draining.

Alluvial soils are confined to principal river valleys and stream channels, with a wide soil textural range and variable drainage. However, the alluvial soils encountered within this region have an average surface % runoff of 44.3%, so it is likely that in this case they would be poorly draining.

These component soils were classed broadly into two groups based on whether they are freely or poorly draining. Drainage classes were created based on information obtained from the both the Macaulay Institute website

and personal communication with Dr. Alan Lilly. GIS map layers were created for each class with poorly draining classes shaded red, pink or orange and freely draining classes coloured blue or grey. These maps were then used to assess the spatial variation in soil permeability across a survey area and its potential impact on runoff.

Glossary of Soil Terminology

Calcareous: Containing free calcium carbonate.

Gley: A sticky, bluish-grey subsurface layer of clay developed under intermittent or permanent water logging.

Podzol: Infertile, non-productive soils. Formed in cool, humid climates, generally freely draining.

Rankers: Soils developed over noncalcareous material, usually rock, also called 'topsoil'.

Regosol: coarse-textured, unconsolidated soil lacking distinct horizons. In Scotland, it is formed from either quartzose or shelly sands.

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 and 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 feed (Bedard and Gauthier, 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 Natural Heritage website). 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. and N. DeLuca (1999). Seasonal enumeration of faecal coliform bacteria from the faeces of Ring-billed gulls (*Larus delawarensis*) and Canada geese (*Branta canadensis*). *Applied and Environmental Microbiology*, 65:5628-5630.

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

Lisle, J.T., Smith, J.J., Edwards, D.D., and McFeters, G.A. (2004). Occurrence of microbial indicators and *Clostridium perfringens* in wastewater, water column samples, sediments, drinking water and Weddell Seal faeces collected at McMurdo Station, Antarctica. *Applied and Environmental Microbiology*, 70:7269-7276.

Scottish Natural Heritage. http://www.snh.org.uk/publications/on-line/wildlife/otters/biology.asp. Accessed October 2007.

Tables of Typical Faecal Bacteria Concentrations

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

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

Source: Kay, D. et al (2008) Faecal indicator organism concentrations in sewage and treated effluents. *Water Research* 42, 442-454.

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: Adapted from Geldreich 1978 by Ashbolt et al in World Health Organisation (WHO) Guidelines, Standards and Health. 2001. Ed. by Fewtrell and Bartram. IWA Publishing, London.

Statistical Data

One-way ANOVA: Log_*E. coli* versus Season

```
Source  DF      SS     MS     F      P
Season   3  13.115  4.372  9.60  0.000
Error   50  22.773  0.455
Total   53  35.889

S = 0.6749   R-Sq = 36.54%   R-Sq(adj) = 32.74%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level    N    Mean   StDev  ---------+---------+---------+---------+
autumn  11  2.5488  0.9075                      (-------*-------)
spring  15  1.4595  0.4380   (------*------)
summer  16  2.3387  0.7336                    (------*------)
winter  12  1.4373  0.5860  (-------*-------)
                           ---------+---------+---------+---------+
                                  1.50      2.00      2.50      3.00

Pooled StDev = 0.6749


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

Individual confidence level = 98.95%


Season = autumn subtracted from:

Season    Lower   Center    Upper  ---------+---------+---------+---------+
spring  -1.8016  -1.0893  -0.3770   (------*------)
summer  -0.9128  -0.2100   0.4928            (------*------)
winter  -1.8604  -1.1114  -0.3624  (-------*------)
                                  ---------+---------+---------+---------+
                                        -1.0       0.0       1.0       2.0


Season = spring subtracted from:

Season    Lower   Center   Upper  ---------+---------+---------+---------+
summer   0.2344   0.8793  1.5241                      (------*-----)
winter  -0.7171  -0.0221  0.6728             (------*------)
                                 ---------+---------+---------+---------+
                                       -1.0       0.0       1.0       2.0


Season = summer subtracted from:

Season    Lower   Center    Upper  ---------+---------+---------+---------+
winter  -1.5866  -0.9014  -0.2162     (------*------)
                                  ---------+---------+---------+---------+
                                        -1.0       0.0       1.0       2.0
```

Hydrographic Methods

The new EU regulations require an appreciation of the hydrography and currents within a region classified for shellfish production with the aim to "determine the characteristics of the circulation of pollution, appreciating current patterns, bathymetry and the tidal cycle." This document outlines the methodology used by Cefas to fulfil the requirements of the sanitary survey procedure with regard to hydrographic evaluation of shellfish production areas. It is written as far as possible to be understandable by someone who is not an expert in oceanography or computer modelling. A glossary at the end of the document defines commonly used hydrographic terms e.g. tidal excursion, residual flow, spring-neap cycle etc.

The hydrography at most sites will be assessed on the basis of bathymetry and tidal flow software only. Selected sites will be assessed in more detail using either: 1) a hydrodynamic model, or 2) an extended consideration of sources, available field studies and expert assessment. This document will consider the more basic hydrographic processes and describes the common methodology applied to all sites.

Background processes

Currents in estuarine and coastal waters are generally driven by one of three mechanisms: 1) Tides, 2) Winds, 3) Density differences.

Tidal flows often dominate water movement over the short term (approximately 12 hours) and move material over the length of the *tidal excursion*. Tides move water back and forth over the tidal period often leading to only a small net movement over the 12 hours tidal cycle. This small net movement is partly associated with the *tidal residual* flow and over a period of days gives rise to persistent movement in a preferred direction. The direction will depend on a number of factors including the bathymetry and direction of propagation of the main tidal wave.

Wind and density driven current also lead to persistent movement of water and are particular important in regions of relatively low tidal velocities characteristic of many of the water bodies in Scottish waters. Whilst tidal flows generally move material in more or less the same direction at all depths, wind and density driven flows often move material in different directions at the surface and at the bed. Typical vertical profiles are depicted in Figure 1. However, it should be understood that in a given water body, movement will often be the sum of all three processes.

In sea lochs, mechanisms such as "wind rows" can transport sources of contamination at the edge of the loch to production areas further offshore. Wind rows are generated by winds directed along the main length of the loch. An illustration of the waters movements generated in this way is given in Figure 2. As can be seen the water circulates in a series of cell that draw material across the loch at right angles to the wind direction. This is a particularly common situation for lochs with high land on either side as these tend to act as a steering mechanism to align winds along the water body.

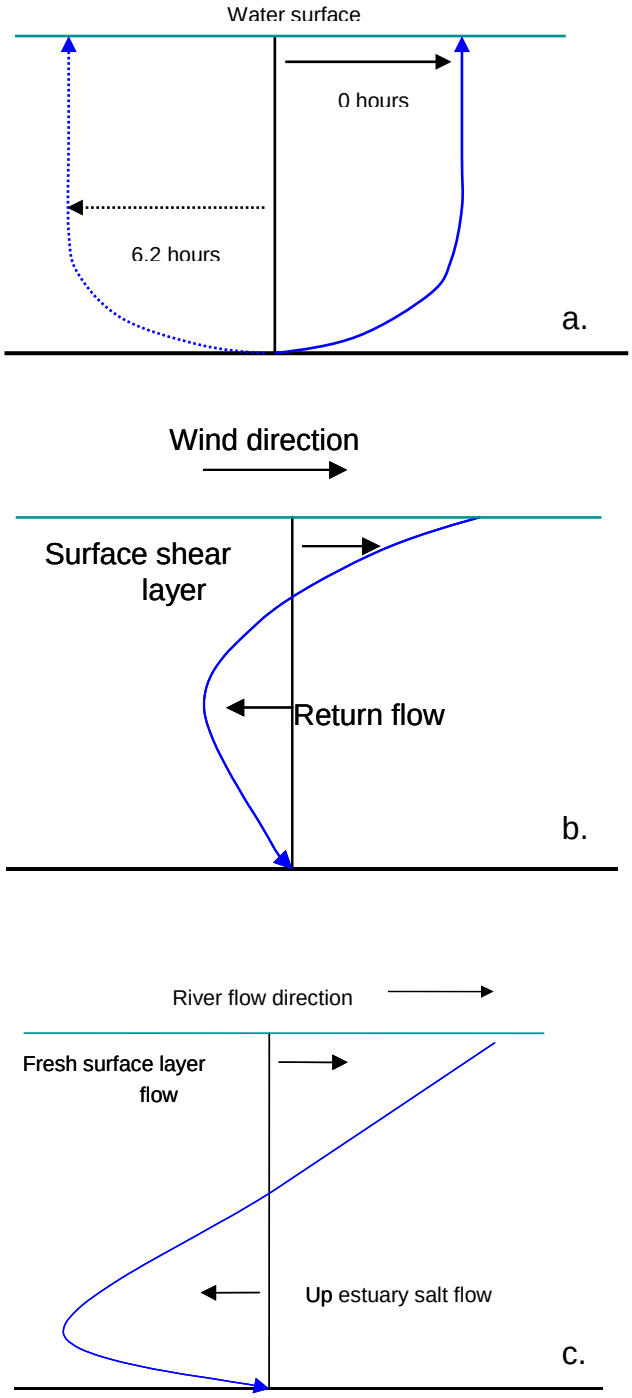

Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction over a period of 6.2 hours. b) wind driven current profile, c) density driven current profile.

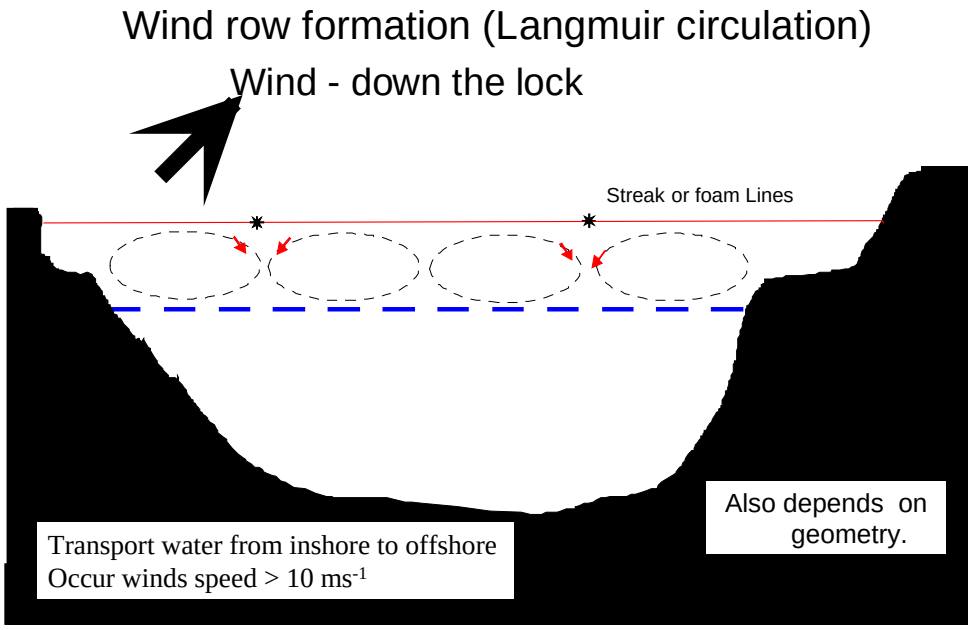

Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Non-modelling Assessment

In this approach the assessment requires a certain amount of expert judgment and subjectivity enters in. For all production areas, the following general guidelines are used:

1. Near-shore flows will generally align parallel to the shore.
2. Tidal flows are bi-directional, thus sources on either side of a production area are potentially polluting.
3. For tidal flows, the tidal excursion gives an idea of the likely main 'region of influence' around an identified pollutant source.
4. Wind driven flows can drive material from any direction depending on the wind direction. Wind driven current speeds are usually at a maximum when the wind direction is aligned with the principle axis of the loch.
5. Density driven flows generally have a preferred direction.
6. Material will be drawn out in the direction of current, often forming long thin 'plumes'.

Many Scottish shellfish production areas occur within sea lochs. These are fjord-like water bodies consisting of one or more basins, deepened by glacial activity and having relatively shallow sills that control the mixing and flushing processes. The sills are often regions of relatively high currents, while the basins are much more tranquil often containing higher density water trapped below a fresh lower density surface layer. Tidal mixing primarily occurs at the sills.

The catalogue of Scottish Sea Loch produced by the SMBA is used to quantify sills, volume fluxes and likely flow velocities. Because the flow is so constrained by the rapidly varying bathymetry, care has to be used in the extrapolation of direct measurements of current flow. Mean flow velocities can be estimated at the sills by using estimates of the sill area and the volume change through a tidal cycle. This in turn can be used to estimate the maximum distance travelled in a tidal cycle in the sill area. Away from the sill area, tidal velocities are general low and transport events are dominated by wind or density effects. Sea Lochs

generally have a surface layer of fresher water; the extent of this depends on freshwater input, sill depth and quantity of mixing.

In addition to movement of particles by currents, dilution is also an important consideration. Dilution reduces the effect of an individual point source although at the expense of potentially contaminating a larger area. Thus class A production areas can be achieved in water bodies with significant faecal coliform inputs if no transport pathway exists and little mixing can occur. Conversely a poor classification might occur where high mixing causes high and permanent background concentrations arising from many weak diffuse sources.

References

European Commission 1996. Report on the equivalence of EU and US legislation for the Sanitary Production of Live Bivalve Molluscs for Human Consumption. EU Scientific Veterinary Committee Working Group on Faecal Coliforms in Shellfish, August 1996.

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.

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. The strongest tides in a month are called spring tides and the weakest are called neap tides. Spring tides occur every 14 days with neaps tides occurring 7 days after springs. Both tidal range and tidal currents are strongest at Spring 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. Often a surface flow at the surface is accompanied by a compensating flow in the opposite direction at the bed (see figure 1).

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.

Shoreline Survey Report

Prod. area:	Loch Spelve: Croggan Pier
Site name:	Croggan Pier (AB 199 055 13)
Species:	Pacific oyster
Harvester:	Jeff & Jean Menzies
Local Authority:	Argyll & Bute Council
Status:	Existing
Date Surveyed:	31st August 2011
Surveyed by:	Michelle Price-Hayward, Ewan McDougall
Nominal RMP:	NM 704 274
Area Surveyed:	Croggan Pier eastward to Rubha nan Sailthean

Weather observations

Sky overcast, dry overnight. Temperature 14.5˚C. Winds calm.
Survey undertaken on dropping tide, with strong tidal flows observed west to east.

Site Observations

Fishery

Pacific oysters are grown in mesh bags laid on 6 raised, perforated steel beds between two rock groynes on the intertidal shoreline east of Croggan Pier. The racks and bags are pressure washed periodically to keep seaweed, sea squirts and other growth from adhering to the bags and interfering with water flow. Likewise the seabed in the small embayment is kept clear to allow unimpeded flow of water around the site.

Harvesting may occur at any time of year, in accordance with demand. The farm may be expanded deeper into the loch in the future.

Sewage/Faecal Sources

Seven homes line the southern shoreline adjacent to the fishery. Only three of these are reported to be permanently occupied, with the remainder used as holiday lets. The harvester, who lives in one of the homes, reported that there is no mains sewerage provision to the area and that the homes are all on individual septic systems as far as they are aware. Two septic tanks were observed, and one discharge through a culvert under the road that appeared to have septic content. No pipes were observed to discharge directly to the shore. The tank observed at the farmhouse east of the fishery had a perforated pipe leading from the tank to underground, and is presumed to be on soakaway. No odour was detected and the house appeared to be unoccupied.

Livestock and wildlife were also observed, and are described further below.

Farming and livestock

A large number of sheep were present on the shoreline adjacent to the fishery during the survey. The harvester reported that the animals had been brought down the day before. Lambs were being separated from the ewes in preparation for shipment to market. Cattle droppings were also seen along the shoreline, though no cattle were seen. The sampling officer identified that cattle were occasionally present on the shore adjacent to the fishery and that the harvesters would chase them off the area when they could.

Seasonal Population

Many of the homes are only seasonally occupied. There are no other tourist attractions or facilities in the vicinity.

Boats/Shipping

A small pontoon jetty was positioned at the shoreline west of the fishery. This was used by 2 small open boats during the survey. In addition, two sailing yachts were observed, one passing out of the loch and one waiting outside the entrance for the tide to turn.

Land Use

Land to the south of the fishery is occupied by a small number of holiday homes and grazing land. Land on the north shore opposite the fishery was steeply sloped and covered with rough grassland, bracken and small areas of deciduous woodland. Two people were observed breaking camp near the mouth of the loch on the north shore.

Watercourses

Small watercourses were distributed along the south shoreline, as well as some ditches which drained water away from pastures around the houses. Those actively flowing at the time of survey were recorded, measured and sampled. All others were recorded only.

Wildlife/Birds

An otter latrine and large male otter were observed near the shore east of the fishery during the survey. A group of 9 gulls were observed at the west end of the fishery. No other groups of birds or other animals were observed.

Dimensions and flows of watercourses are estimated at the most convenient point of access and not necessarily at the point at which the watercourses enter the loch.

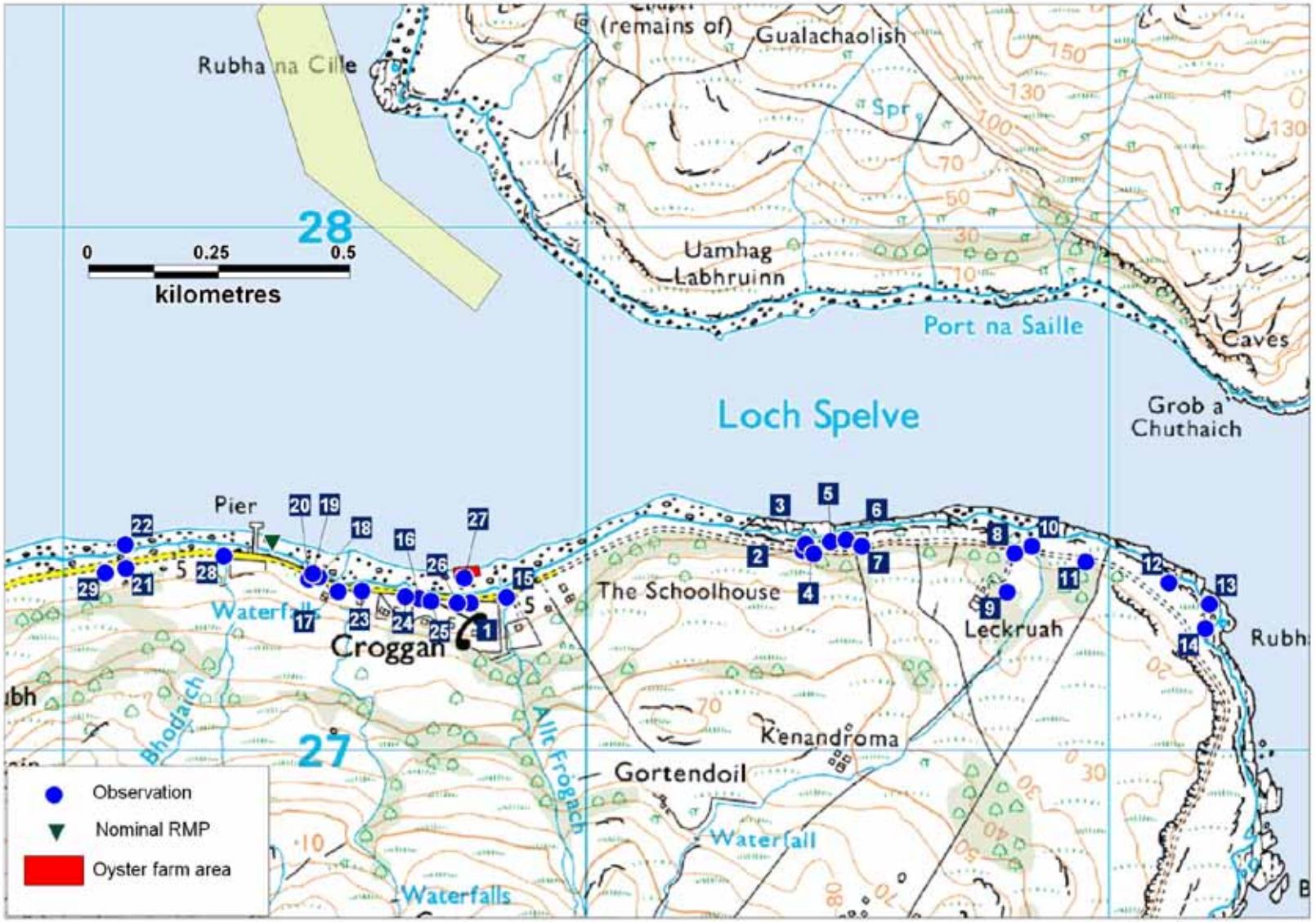

Figure 1. Map of Shoreline Observations

Table 1. Shoreline Observations

No.	Date	Time (GMT)	NGR	East	North	Associated photograph	Description
1	31/08/2011	09:23:39	NM 70778 27284	170778	727284		Sheep on shore and in fenced area above road. 70 counted, though others likely out of view. Sheep droppings numerous.
2	31/08/2011	09:42:03	NM 71415 27384	171415	727384		Small stream running under path, over and through rocks. Not suitable for measurement or sampling. Seawater sample LSC1
3	31/08/2011	09:44:46	NM 71421 27397	171421	727397		Cattle droppings
4	31/08/2011	09:50:35	NM 71436 27378	171436	727378		Sheep droppings present but not numerous
5	31/08/2011	09:53:53	NM 71469 27401	171469	727401		Very small stream, barely flowing through fissure in rock. Cattle hoof prints and droppings in muddy areas upstream.
6	31/08/2011	09:58:36	NM 71499 27404	171499	727404		Stagnant pond with outflow dribbling over rocks to sea. Cattle droppings around pond, green algae on wet areas. No dwellings or livestock visible on opposite shore
7	31/08/2011	10:14:20	NM 71528 27392	171528	727392		Stream, wet but not flowing
8	31/08/2011	10:20:27	NM 71821 27379	171821	727379		17 sheep, house uphill beyond trees. Tide flowing strongly eastward, approx 1 m/s, sampling officer reports spring flow max approx 4-5 kts
9	31/08/2011	10:23:23	NM 71807 27304	171807	727304		Septic tank - outflow to land. Part of perforated pipe visible above ground. No odour, house appears unoccupied. Cattle droppings
10	31/08/2011	10:33:10	NM 71854 27392	171854	727392	Figure 3	Stream, 130cm x 9cm deep, flow 0.037 m/s, SD 0.009. Water sample LSC2. Banks trampled and cattle droppings around
11	31/08/2011	10:43:51	NM 71957 27362	171957	727362		Ditch, water ponded with aquatic plants present. Not flowing.
12	31/08/2011	10:51:22	NM 72117 27322	172117	727322		Otter latrine and slide, small trickle of water barely flowing across rock.
13	31/08/2011	11:02:44	NM 72194 27281	172194	727281		Seawater sample LSC3, 1 otter, at least 2 campers visible on opposite shore, sailing yacht passing out of loch
14	31/08/2011	11:21:42	NM 72187 27235	172187	727235	Figure 4	Photo taken looking east. No dwellings, small shingle beach. Otter from previous obs still watching from just offshore
15	31/08/2011	11:45:59	NM 70848 27295	170848	727295	Figure 5,6	Stream, flows past farm and through culvert under road. 17cm x 3 cm, flow 0.436 SD 0.008. Water sample LSC4. 2 photos 1 N 1 W
16	31/08/2011	11:58:12	NM 70681 27292	170681	727292		Drainage ditch, wet but not flowing. House above
17	31/08/2011	12:01:42	NM 70526 27306	170526	727306		Stream below waterfall, flows through culvert under road. Measured just above culvert. 54cm x 7cm flow 0.343 m/s SD0.021. Water sample LSC5
18	31/08/2011	12:12:48	NM 70488 27333	170488	727333		Fence in stone wall, small weather station, and house on opposite side of road.
19	31/08/2011	12:14:30	NM 70477 27340	170477	727340	Figure 7	Pipe through road, trickling. No odour but black/green algae. Too low to measure, water sample LSC6 taken from puddle area on rock
20	31/08/2011	12:22:43	NM 70469 27329	170469	727329		Septic tank discharges to ditch that flows to culvert.
21	31/08/2011	12:34:24	NM 70119 27350	170119	727350		Very small stream, barely flowing.
22	31/08/2011	12:37:30	NM 70118 27395	170118	727395		Seawater sample LSC7
23	31/08/2011	12:51:35	NM 70571 27307	170571	727307		House

No.	Date	Time (GMT)	NGR	East	North	Associated photograph	Description
24	31/08/2011	12:53:09	NM 70654 27296	170654	727296		House, temporary jetty, 2 small open boats
25	31/08/2011	12:54:21	NM 70703 27287	170703	727287		House
26	31/08/2011	12:55:18	NM 70754 27283	170754	727283		House
27	31/08/2011	13:05:53	NM 70767 27331	170767	727331	Figure 8	Oyster sample 1 taken from shore end of middle rack. Farm is 5 racks wide. Photo. Seawater sample LSC8 taken approx 3m off end of rack.
28	31/08/2011	13:59:30	NM 70306 27373	170306	727373		Culverted stream, pipe diameter 60cm. Flow taken in bucket - 15l volume, average fill time 5s.
29	31/08/2011	14:11:23	NM 70079 27341	170079	727341		9 gulls
	15/09/2011	11:20:00	NM 70477 27338	170477	727338		Water sample LSC6 retaken due to loss of sample

Photographs referenced in the table can be found attached as Figures 3-8.

Sampling

Water and shellfish samples were collected at sites marked on the map. Samples were transferred to a Biotherm 10 box with ice packs and shipped to Glasgow Scientific Services on 31 August for *E. coli* analysis. Samples were received by the laboratory on 1 September. The sample temperature on arrival was 4.2C, which was within the recommended temperature range of 2-8C. Sample LSC6 was missed by the laboratory as the container was wrapped in the disposable glove used to collect the sample. This sample was retaken on 15 September. All results are shown in Tables 2 and 3, and shown mapped in Figure 2.

Seawater samples were tested for salinity by the laboratory and results reported in mg Chloride per litre. These results have been converted to parts per thousand (ppt), and are shown in Table 2.

Table 2. Water Sample Results

No.	Date	Sample	Grid Ref	Type	*E. coli* (cfu/100 ml)	Salinity (ppt)
1	31/08/11	LSC1	NM 71415 27384	Seawater	16	33.6
2	31/08/11	LSC2	NM 71854 27392	Freshwater	<100	
3	31/08/11	LSC3	NM 72194 27281	Seawater	14	
4	31/08/11	LSC4	NM 70848 27295	Freshwater	1200	
5	31/08/11	LSC5	NM 70526 27306	Freshwater	<100	
6	31/08/11	LSC6	NM 70477 27340	Septic	NA	
7	31/08/11	LSC7	NM 70118 27395	Seawater	41	34.9
8	31/08/11	LSC8	NM 70767 27331	Seawater	0	34.7
9	31/08/11	LSC9	NM 70306 27373	Freshwater	<100	
10	15/09/11	LS-15-09-11	NM 70477 27338	Freshwater/ Septic	2000	

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	*E. coli* (MPN/100 g)
1	06/07/11	LM shellfish 1	NM 6427 7190	Pacific oyster	20

Figure 2. Water sample results map

Photographs

Figure 3. Stream discharging to loch

Figure 4. View eastward over shingle beach at entrance to loch

Figure 5. Stream flowing past farm house

Figure 6. View looking westward toward oyster farm from same point as Figure 5.

Figure 7. Culvert through road

Figure 8. Oyster farm