Scottish Sanitary Survey Project

Sanitary Survey Report
Loch Linnhe
AB 172
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Cefas

Food Standards Agency
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Buidheann Inbhe-Bìdhe

Report Distribution – Loch Linnhe

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* Distribution of both draft and final reports to relevant agency personnel and harvesters is undertaken by FSAS.

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1. General Description

Loch Linnhe lies on the western coast of the Scotland. It is approximately 50 km in length and varies between 1 and 15 km in width. Loch Linnhe is fed by Loch Eil at its most northernmost point, and opens to the Firth of Lorne in the south. The loch narrows at Corran, where a car ferry crosses. The shellfish production area called Loch Linnhe is situated in the bay of Port Ramsay on the north-western shore of the island of Lismore. Shuna Island is located to the north-east of Lismore and the settlement of Port Appin is on the mainland to the east of the northern tip of the island. Fort William, the largest town in the Scottish highlands, lies at the north eastern end of Loch Linnhe.

Figure 1.1 shows the location of Loch Linnhe and Lynn of Lorn on the western coast of Scotland.

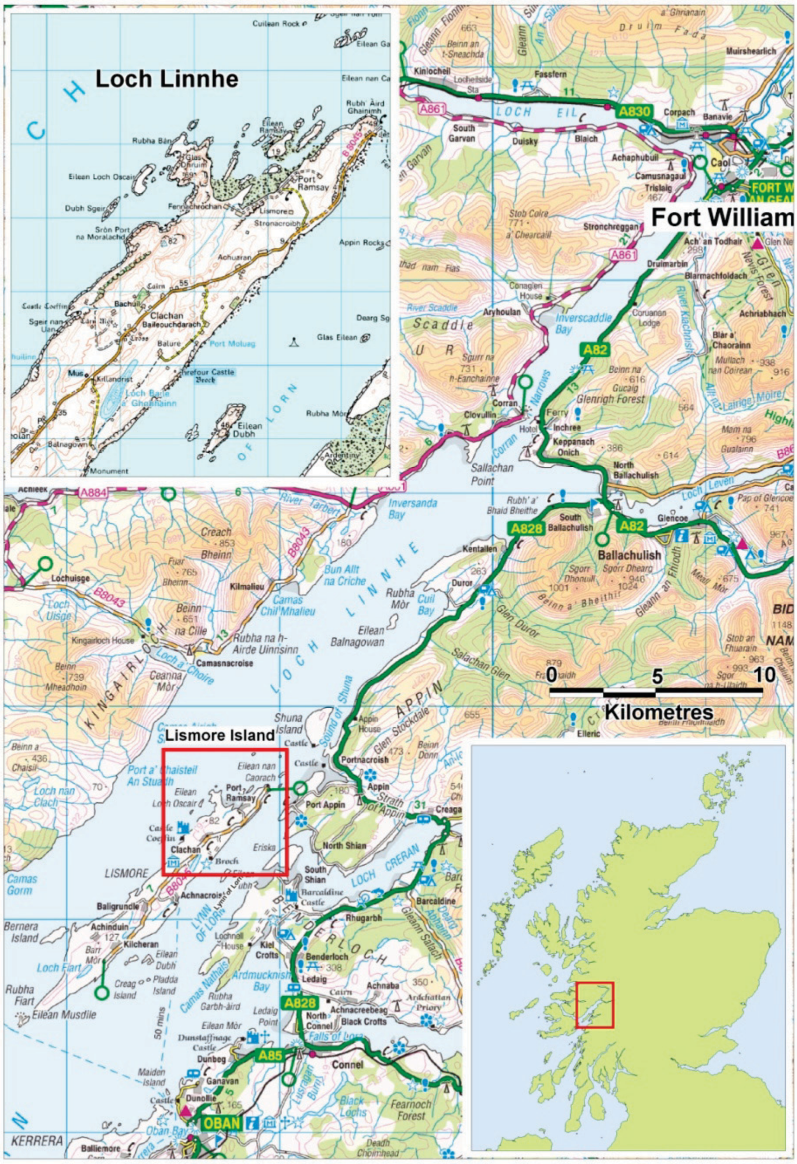


Figure 1.1 Location of Loch Linnhe

2. Fishery

The sanitary survey is being undertaken as a result of the high ranking obtained by Loch Linnhe on the risk matrix. The risk score was primarily driven by species, the number of unusual results (i.e. results outwith classification) and recent changes in classification.

Table 2.1 Loch Linnhe

Production Area	Site	SIN	Species	RMP
Loch Linnhe	Loch Linnhe	AB 172 047 13	Pacific oysters	NM 876 455

The Loch Linnhe production area is defined as an area bounded by lines drawn between NM 8948 4634 to NM 8860 4770 (Cuilean Rock) to NM 8470 4670 to NM 8460 4264. The RMP is located at NM 876 455.

A designated shellfish growing water (SGW) falls within the Loch Linnhe production area.

Figure 1.1 shows the location of the Loch Linnhe oyster trestles, production area, crown estate lease areas, representative monitoring point (RMP) and shellfish growing water boundary.

The Pacific oysters are grown in poches on trestles and are harvested by hand. Harvesting is undertaken year-round.

There is a second seabed lease at Eilean Nam Meann, a short distance to the north-west of the oyster farm, where the harvester proposes placing a mussel raft on a trial basis.

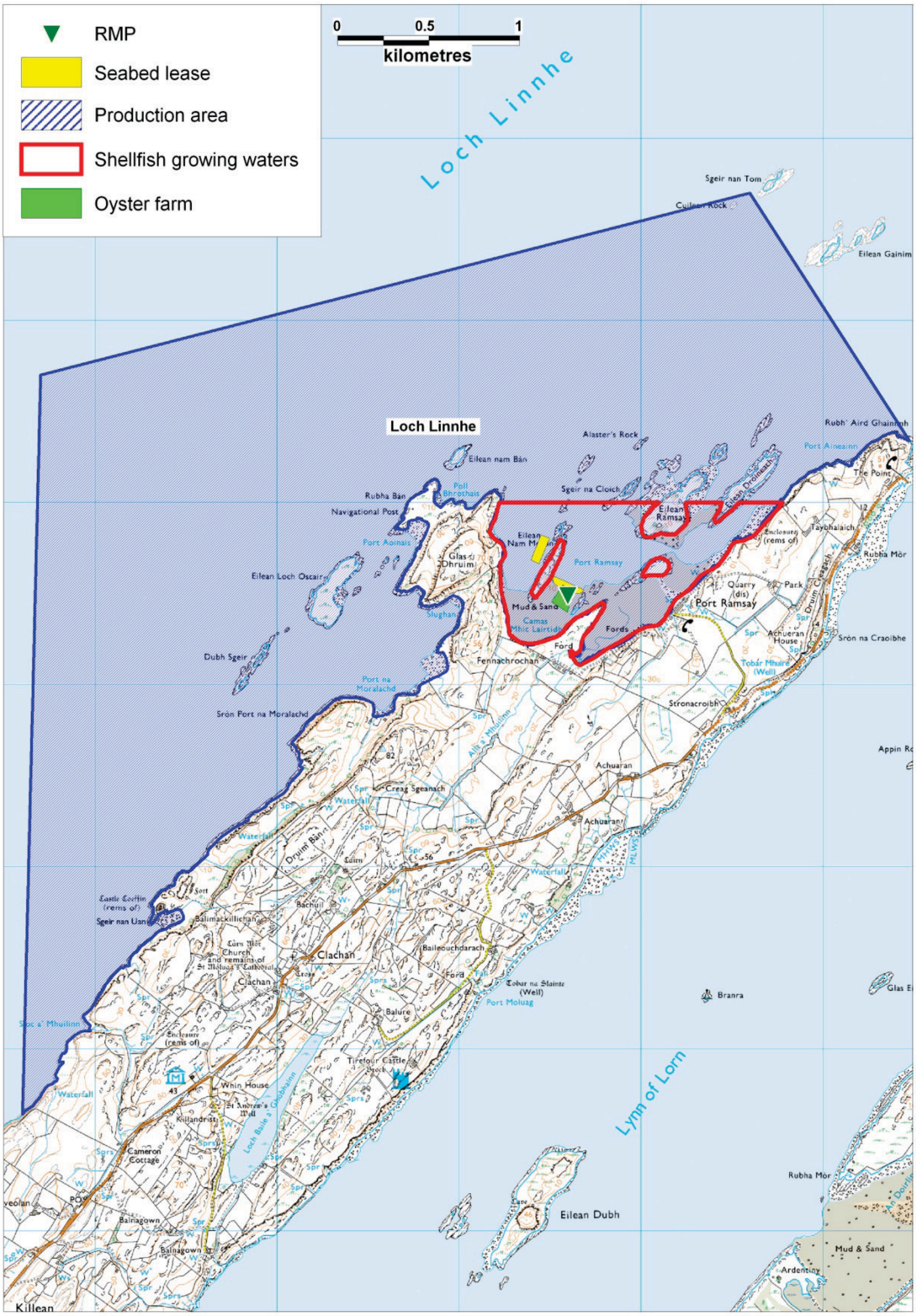


Figure 2.1 Loch Linnhe and Lynn of Lorn: Eilean Dubh shellfisheries

3. Human Population

Figure 3.1 shows information obtained from the General Register Office for Scotland on the population within the census output areas in the vicinity of the oyster fishery at Loch Linnhe. The last census was undertaken in 2001.

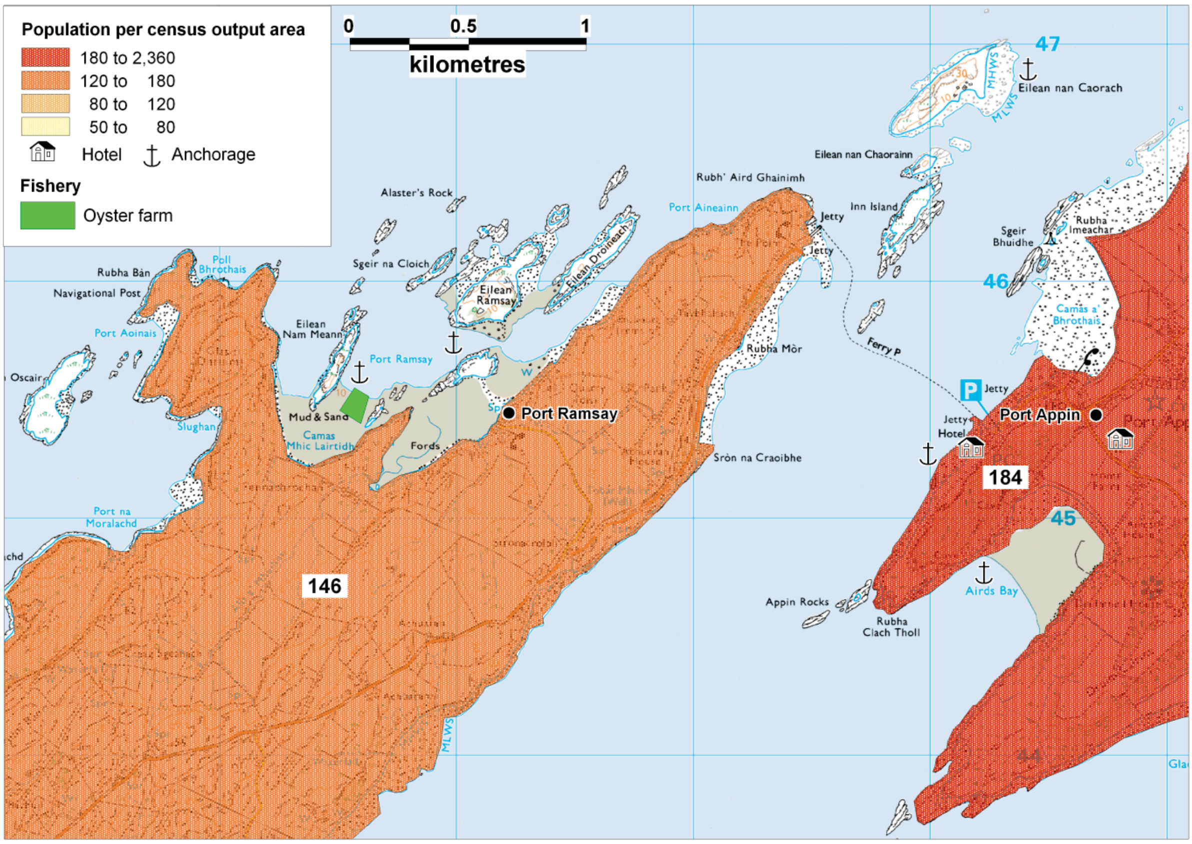


Figure 3.1 Human population adjacent to Loch Linnhe oyster fishery

There are two population census areas within the proximity of the fishery at Loch Linnhe, with populations of 146 and 184. Both census areas are relatively large and sparsely populated.

There are no large centres of population in the area. The total population of Lismore at the 2001 census was 146. There are five main settlements on the island; Port Ramsay, Clachan, Achnacroish, Kilcheran and Achinduin. Port Ramsay is a small community located on the immediately east of the fishery. The other settlements are situated further south on the island. Four self-catering cottages are located in Port Ramsay. Elsewhere on the island there e are 3 guest houses and 6 further self-catering cottages plus a post office/shop, public hall, cafe and heritage museum. There is also a primary school located near Achnacroish towards the centre of the island. A local source identified that approximately 12,000 people visit Lismore each year (Lismore Historical Society).

On the mainland adjacent to Lismore Island is the small settlement of Port Appin which also has some tourist accommodation.

There is a daily passenger ferry from Port Appin to Lismore and a small daily car ferry from Oban to Achnacroish, Lismore. There are two anchorages within the bay at Port Ramsay. One is directly in front of the oyster trestles and on the day of the survey a large yacht and fishing boat were observed anchored there. Three smaller yachts were also moored adjacent to the cottages and holiday homes in Port Ramsay. There are three additional anchorages in the area, one is located east of Eilean nan Caorach, one is in Airds Bay and the third is near the passenger ferry jetty at Port Appin.

The most important potential source of human pollution will therefore be the settlement of Port Ramsay to the east of the oyster farm. There may also be localised impacts from boats moored in the bay. There is likely to be a significant increase in human population in the summer.

4. Sewage Discharges

Scottish Water identified no community septic tanks or sewage discharges for the area surrounding the Loch Linnhe production area. Discharge consents provided by SEPA are listed in Table 4.1. Sanitary or microbiological data were available for some these discharges.

Table 4.1 Discharge consents identified by SEPA

Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Consented/ design PE	Discharges to
CAR/R/1047169	NM 87632 45128	STE	Not stated	Not stated	5	Port Ramsay
CAR/R/1038082	NM 88130 45360	STE	Not stated	Not stated	5	Port Ramsay
CAR/R/1046692	NM 88160 45410	STE	Not stated	Not stated	5	Port Ramsay
CAR/R/1038083	NM 88170 45440	STE	Not stated	Not stated	5	Port Ramsay
CAR/R/1037730	NM 88180 45460	STE	Not stated	Not stated	5	Port Ramsay
CAR/R/1037698	NM 88220 45500	STE	Not stated	Not stated	5	Port Ramsay
CAR/R/1037058	NM 89214 45724	STE	Not stated	Not stated	7	Firth of Lorn
CAR/R/1037811	NM 90180 45300	STE	Not stated	Not stated	5	Loch Linnhe
CAR/R/1028609	NM 90634 45522	STE	Not stated	Not stated	5	Unnamed watercourse
CAR/R/1012088	NM 90510 45580	STE	Not stated	Not stated	5	Lynn of Lorn
CAR/R/1078773	NM 90570 45620	STE	Not stated	Not stated	6	Lynn of Lorn
CAR/L/1000420	NM 90700 45600	STE	Not stated	Not stated	1	Lynn of Lorn

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

Table 4.2 Discharges and septic tanks observed during shoreline surveys

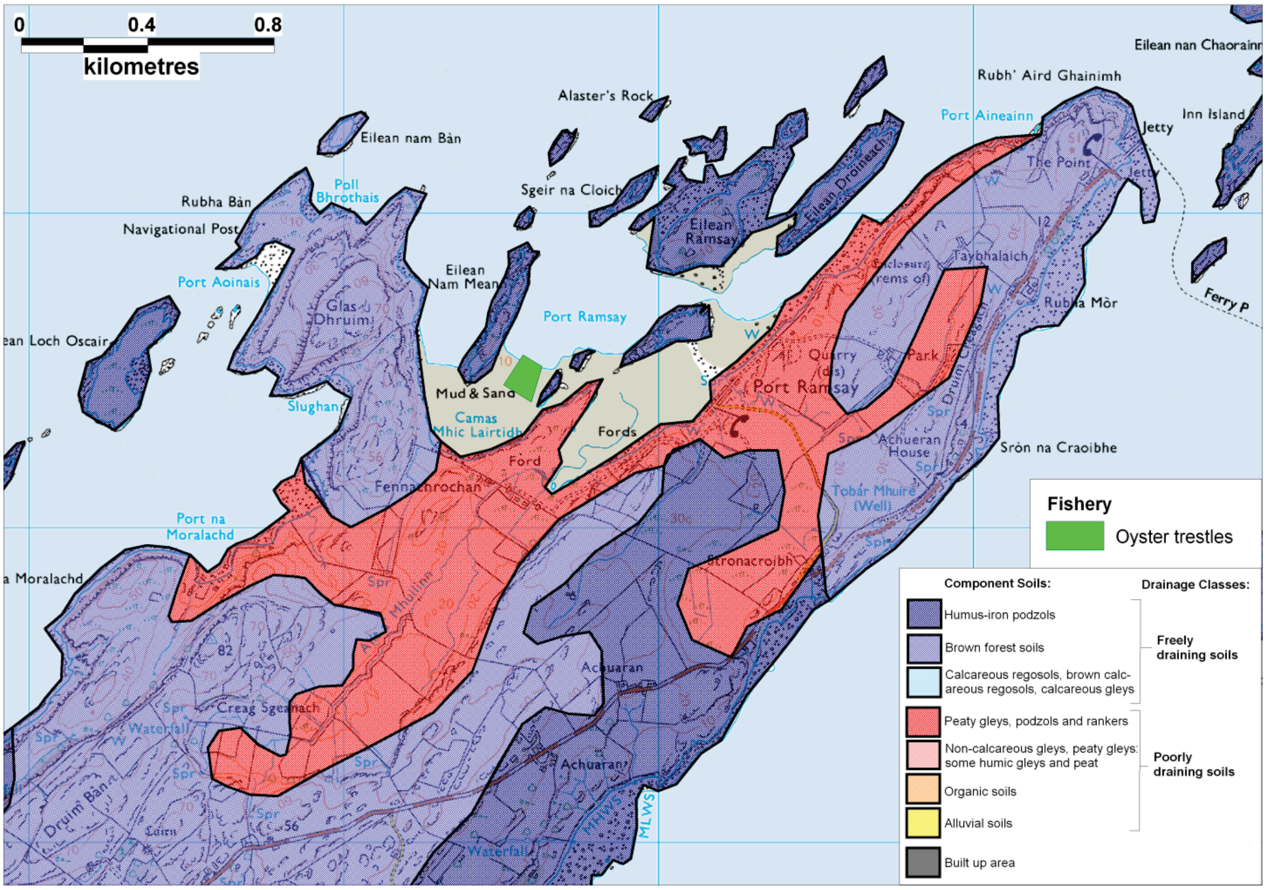
No.	Date	NGR	Description
1	09/09/2010	NM 88240 45469	Septic tank, smells of sewage, no sign of outfall pipe
2	09/09/2010	NM 88233 45464	Septic tank, no sign of outfall pipe
3	09/09/2010	NM 88229 45461	Septic tank, no sign of outfall pipe
4	09/09/2010	NM 88227 45452	Outfall pipe flowing into stream, previously sampled (LINNHE FW2). Sewage flowing out of the pipe at time of observation.
5	09/09/2010	NM 88213 45439	Septic tank, no sign of outfall pipe
6	09/09/2010	NM 88185 45398	Two septic tanks, no sign of outfall pipe
7	09/09/2010	NM 88180 45394	Septic tank, no sign of outfall pipe
8	09/09/2010	NM 88163 45382	Outfall pipe, could not find the end
9	09/09/2010	NM 88152 45350	Two septic tanks, no sign of outfall pipe. Smells of sewage.

During the shoreline survey nine septic tanks and three outfall pipes were observed on the far eastern shoreline, close to the row of cottages and holiday homes in Port Ramsay. Only one of the outfall pipes was flowing at the time of the shoreline survey. The septic tanks not associated with outfall pipes discharged to soakaway. Potential contamination of the shellfishery from sewage discharges will mainly arise from those located at Port Ramsay, although the three discharges at the south east of the bay may also contribute. Of these, the discharge to water will be of the most direct importance.

Figure 4.1 Map of discharges for Loch Linnhe

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.



Produced by Cefas Weymouth Laboratory.

Figure 5.1 Component soils and drainage classes for Loch Linnhe

Three types of component soils are present in the area: peaty gleys, podzols and rankers, brown forest soils and humus-iron podzols. The peaty gleys, podzols and rankers that cover the immediate shoreline south and east of the fishery and also some areas inland are poorly draining and the humus-iron podzols and brown forest soils that cover the immediate shoreline west of the fishery and the majority of the area inland are freely draining. Therefore, the potential for runoff contaminated with *E. coli* from human and/or animal waste will be higher on the southern and eastern sides of the oyster trestles which are adjacent to the areas of poorly draining peaty gleys, podzols and rankers. A stream, (Allt a' Mhuilinn), which discharges to the bay east of the trestles, flows from an area of poor soil drainage.

For information on how these soil types and permeability characteristics were derived, please see the geology and soils document in the appendix.

6. Land Cover

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

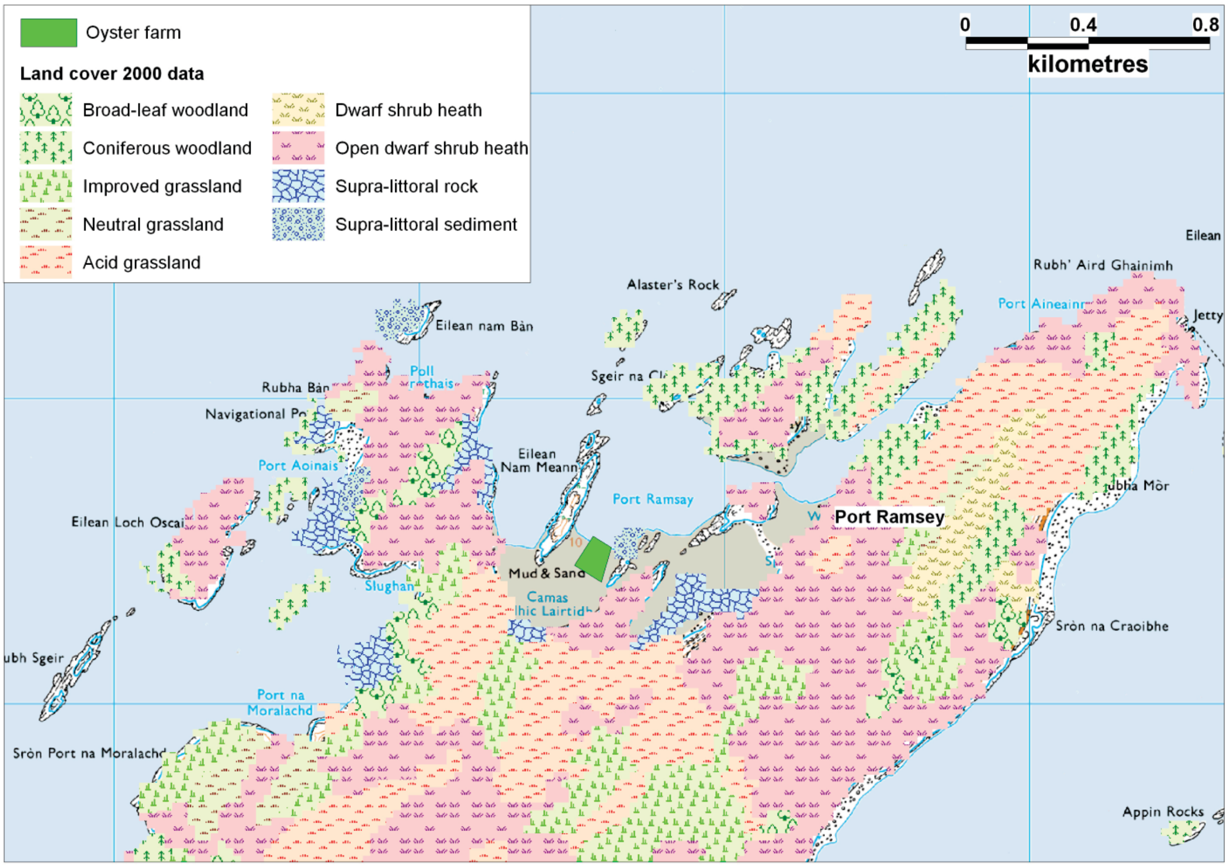


Figure 6.1 LCM2000 class land cover data for Loch Linnhe

The land on the shoreline immediately adjacent to the fishery is predominantly classed as open dwarf shrub heath and acid grassland with some areas of supra-littoral rock. Areas of improved grassland, natural grassland, coniferous woodland and broadleaf woodland can be found on the remaining shoreline and inland areas.

Faecal indicator organism export coefficients for faecal coliform bacteria have been found to be highest for urban catchment areas (1.2 – $2.8x10^{9}$ cfu km^{-2} hr^{-1}) and lower for areas of improved grassland (approximately $8.3x10^{8}$ cfu km^{-2} hr^{-1}) and rough grazing (approximately $2.5x10^{8}$ cfu km^{-2} hr^{-1}) (Kay et al. 2008). Lowest contributions would be expected from areas of woodland (approximately $2.0x10^{7}$ cfu km^{-2} hr^{-1}). 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).

Although not identified specifically in the land cover data, the settlement of Port Ramsey would constitute a developed area though the extent of its coverage is very low relative to the remainder of the area around it.

Therefore, the expected contribution of faecal indicator bacteria attributable to land cover type would be highest along the east shoreline around Port Ramsey and south of the fishery where there is a patch of improved grassland leading onto supra-littoral rock and lower along the remainder of the shoreline.

7. Farm Animals

Agricultural census data to parish level was requested from the Scottish Government. Agricultural census data was provided by the Rural Environment, Research and Analysis Directorate (RERAD) for the parish of Lismore and Appin, encompassing a land area of 377.5 km^2. Reported livestock populations for the parishes in 2008 and 2009 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 Lismore and Appin parish 2008 - 2009

	Lismore and Appin			
	2008		2009	
	Holdings	Numbers	Holdings	Numbers
Pigs	*	*	*	*
Poultry	23	212	24	225
Cattle	42	1,218	40	1,030
Sheep	49	14,795	53	17,285
Horses and ponies	12	66	12	73

* Data withheld for reasons of confidentiality

The Lismore and Appin parish covers the island and some of the adjacent mainland. Due to this, the large area, and missing data for pig holdings, accurate data for the number of livestock on the shore surrounding the Loch Linnhe production area is only available from the shoreline survey (see section 15 and Appendix 7). This only relates to the time of the site visit on the 9th September 2010. The spatial distribution of animals observed and noted during the shoreline survey and boundaries of the Lismore and Appin agricultural parish is illustrated in Figure 7.1.

During the shoreline survey, on the far eastern shoreline approximately 10 sheep were observed fenced in a field adjacent to the shoreline. South of the oyster trestles a further 12 sheep were observed fenced off in a field next to a house and adjacent to the shoreline.

Livestock numbers in the immediate area of the fishery appear relatively low and they do not have access to the shoreline. Faecal contributions to the vicinity of the shellfishery are therefore likely to be low and to occur either via watercourses or, in the case of heavy rainfall, possibly by direct runoff to the shore. Any effects will be from the eastern and southern shores, with the latter predominating due to the proximity to the shellfishery.

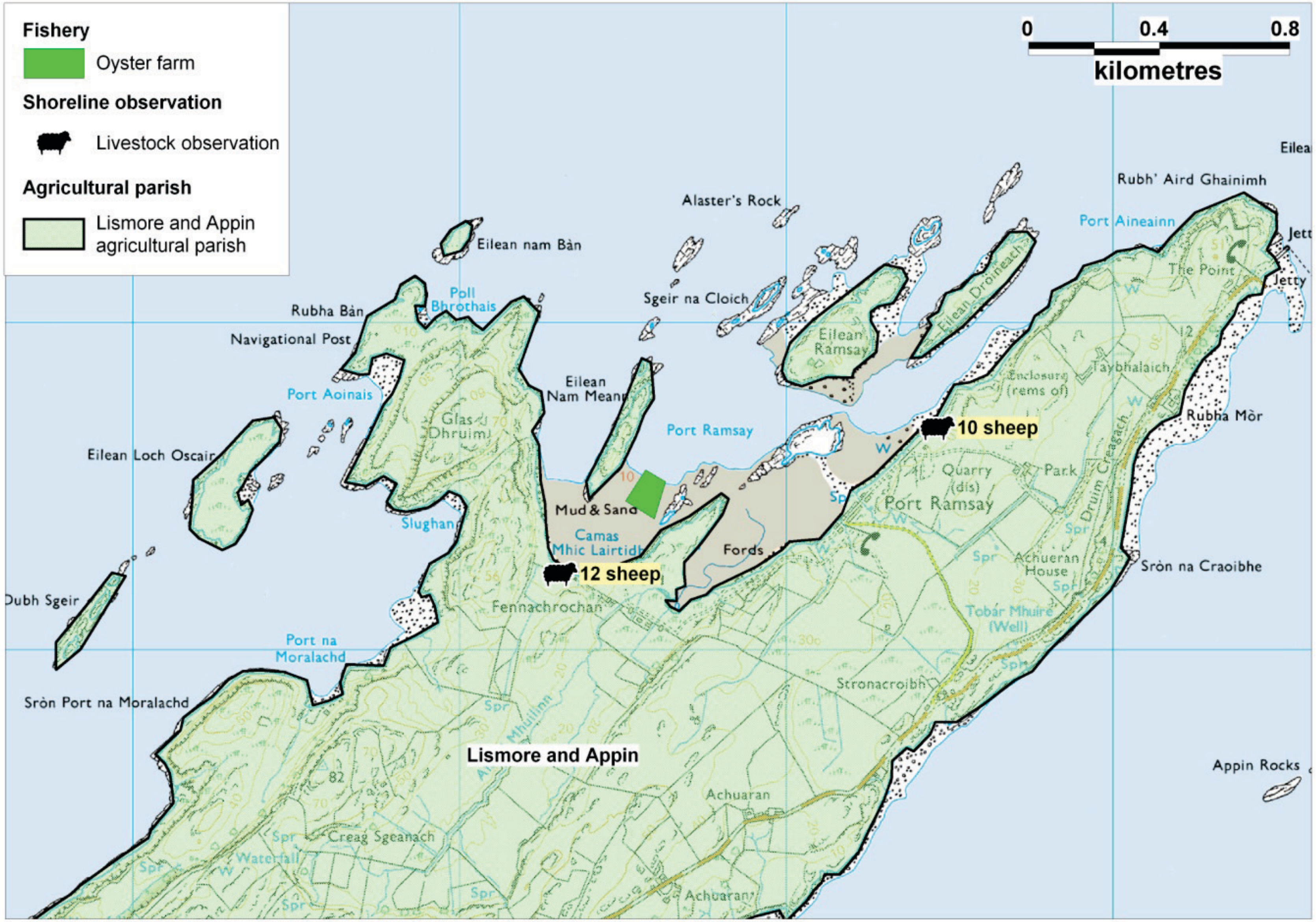


Figure 7.1 Livestock observations at Loch Linnhe

8. Wildlife

A variety of wildlife is present on the Isle of Lismore. The Isle of Lismore community website (2011) reports that seabirds present on the island include gulls, gannets, cormorants, shags, terns, razorbills, guillemots, herons, oyster catchers, plovers, geese, and swans amongst others. There are no resident deer on the island, although they have been recorded as occasionally swimming over from the mainland.

Seals

A commissioned report by Scottish Natural Heritage in 2000 concerning breeding and moulting numbers of common seals around Scotland indicated that the Isle of Lismore is an important site for seals. Numbers during the moult in 1993 were 596 and in 1996 were 591 representing 2.0% in each case of the Scottish total population. In 2000 there were 454 (Scottish Natural Heritage, 2001). The distribution of these populations relative to the shellfishery is unknown. No seals were observed on the day of the shoreline survey.

Birds

Seabird 2000 data has been provided for a 5 km radius of the Loch Linnhe production area. Details of the observations closest to the fishery are shown in Figure 8.1 and indicates that the small islands to the north of the fishery are fairly densely populated with occupied nests of various species of seabirds. A summary of seabird counts within 5 km of the site are listed in Table 8.1. This indicates that the European herring gull is the most common species in the area. Common gulls, European shags, arctic terns and common terns are also common in the area.

Table 8.1 Seabird counts within 5km of the site.

Common name	Species	Count	Method
Arctic Tern	*Sterna paradisaea*	48	Individuals on land/Occupied nests
Common Tern	*Sterna hirundo*	45	Occupied nests
Herring Gull	*Larus argentatus*	488	Individuals on land/Occupied territory or nests
Common Gull	*Larus canus*	114	Individuals on land/Occupied territory or nests
Black Guillemot	*Cepphus grylle*	28	Individuals on land
Great Black-backed Gull	*Larus marinus*	34	Individuals on land/Occupied territory or nests
Lesser Black-backed Gull	*Larus fuscus*	25	Individuals on land
European Shag	*Phalacrocorax aristotelis*	63	Occupied nests
Great Cormorant	*Phalacrocorax carbo*	3	Occupied nests

During the shoreline survey, approximately 12 gulls were observed to the west of the oyster trestles. Species potentially impacting on Loch Linnhe include the following seabirds; gulls, terns, shags and possibly seals. With respect to the available information, the predominant effects of wildlife in the area will be due to the seabird populations located to the north-east of the oyster farm. The effects from other species, such as seals, are likely to be more intermittent and to occur anywhere across the area.

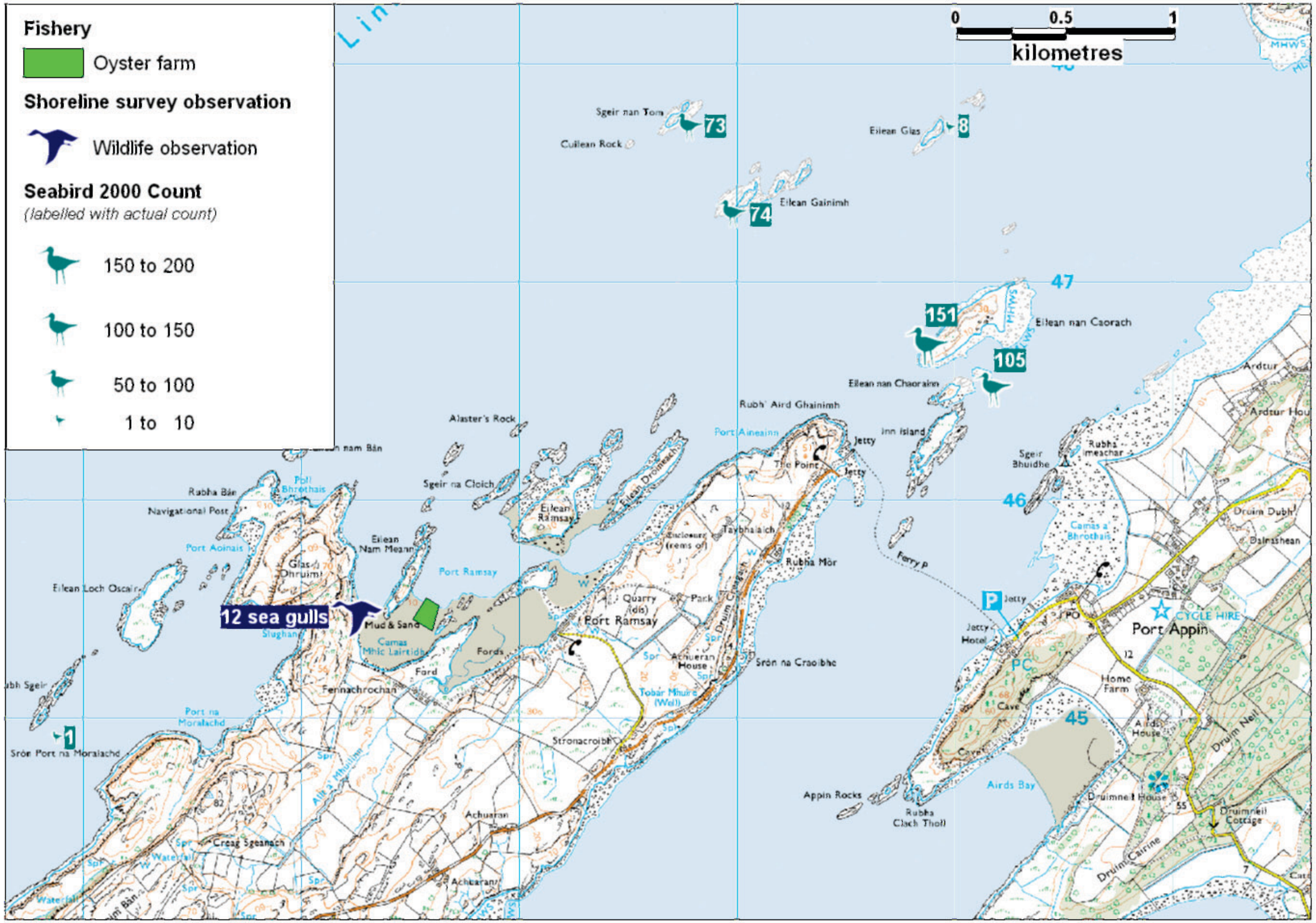


Figure 8.1 Map of seabird distributions

9. Meteorological data

The nearest weather station for which rainfall records were available is located at Lismore: Frackersaig Farm, about 5 km to the southwest of the production area. Rainfall data was available for 2003-2009 inclusive, aside from the months of July 2003, September 2005 and September 2006. Two weather stations for which wind records were available lie about 90 km from the fishery. Tiree lies to the west, and is situated on a low lying island fully exposed to the Atlantic, and Glasgow: Bishopton lies in the Clyde Valley to the south east. Data from the Glasgow: Bishopton weather station is presented here as it is likely to show most similarity to what is experienced at the two production areas as they are situated in a less exposed position. The Clyde valley has an east-west aspect, whereas the Loch Linnhe site at Port Ramsay is most exposed to the north. While overall wind patterns may be broadly similar at Glasgow and the fishery, local topography and the distance between the two locations may result in differences in wind direction and speed. This section aims to describe the local rain and wind patterns and how they may affect the bacterial quality of shellfish at Loch Linnhe.

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). Figures 9.1 and 9.2 present box and whisker plots summarising 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 located at the line within the box. 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 *.

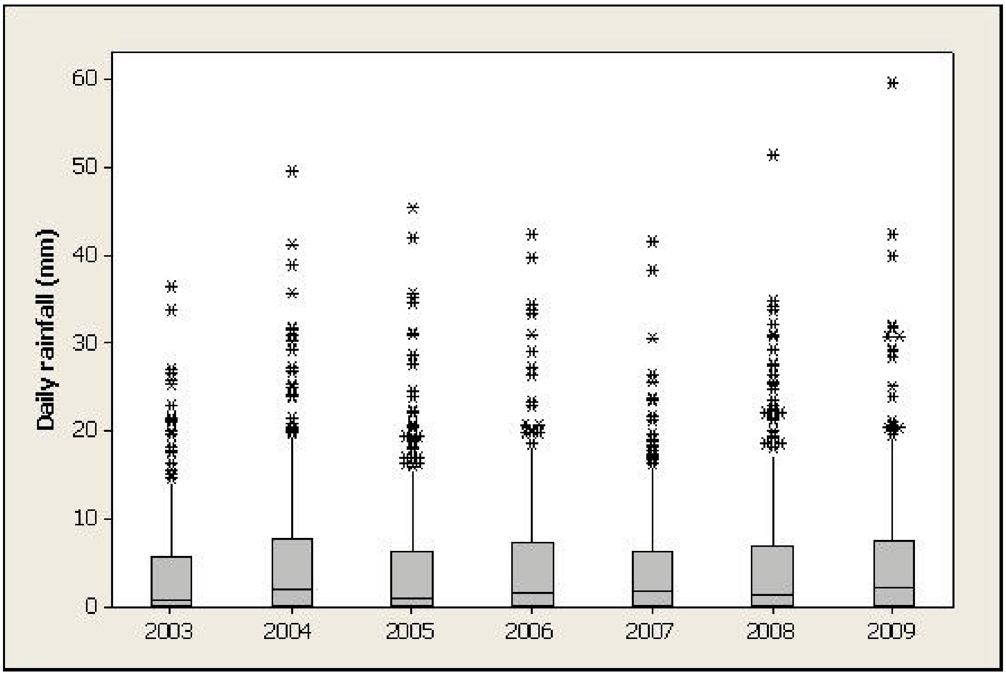


Figure 9.1 Box plot of daily rainfall values by year at Frackersaig Farm, 2003-2009

Figure 9.1 shows that rainfall patterns were very similar between the years presented here, with 2003 the driest and 2004 the wettest. Total annual rainfall at this station is relatively high.

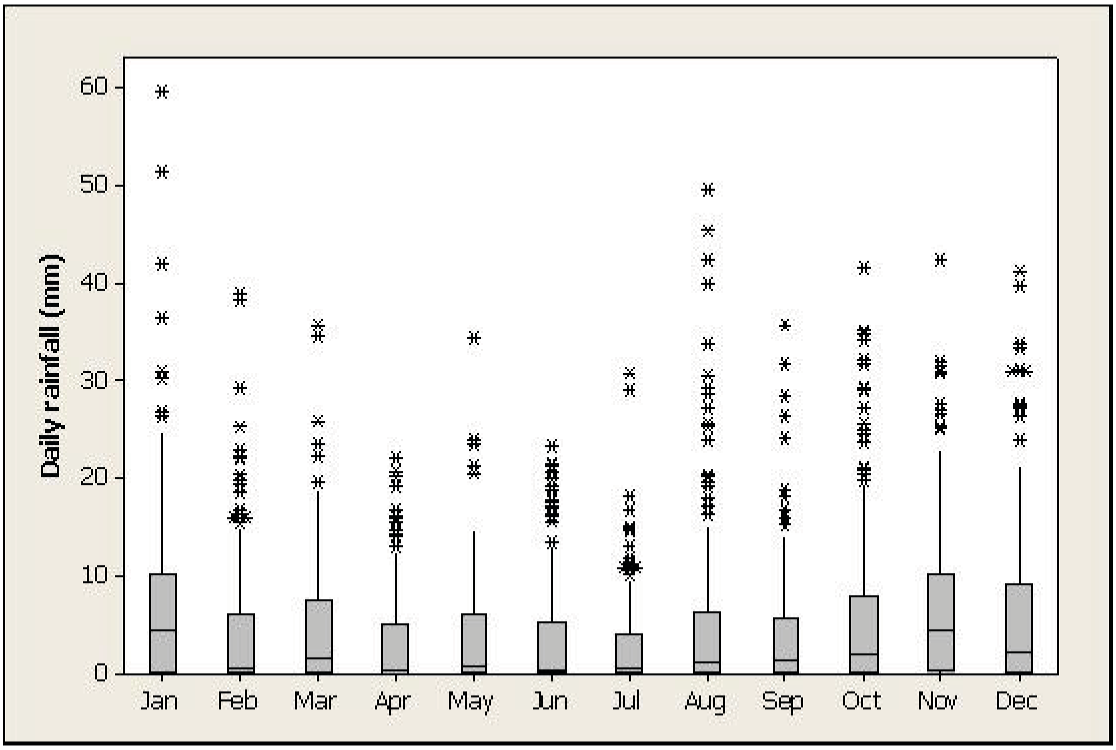


Figure 9.2 Box plot of daily rainfall values by month at Lismore: Frackersaig Farm, 2003-2009

Figure 9.2 shows that weather was wettest from October to January, and driest from April to June. Days with over 20 mm of rainfall occurred during all months, with days showing over 40 mm of rainfall being restricted to the period from August to January. For the period considered here (2003-2009), 44% of days experienced rainfall less than 1 mm, and 17% of days experienced rainfall of 10 mm or more.

It can therefore generally be expected that levels of run-off will be higher during the autumn and winter months. 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 dry periods and when stock levels are at their highest.

9.2 Wind

Wind data collected at the Glasgow: Bishopton weather station is summarised by season and presented in Figures 9.3 to 9.7.

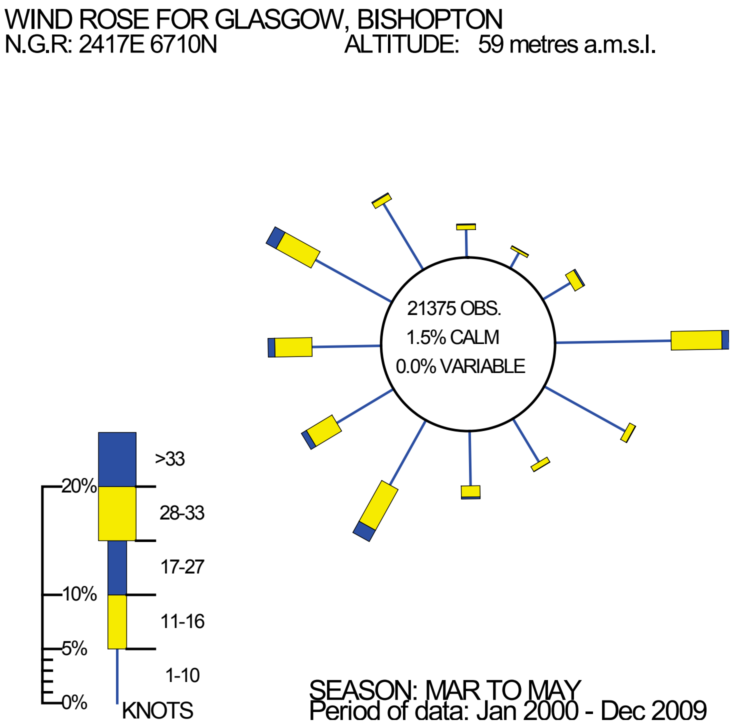


Figure 9.3 Wind rose for Glasgow Bishopton (March to May)

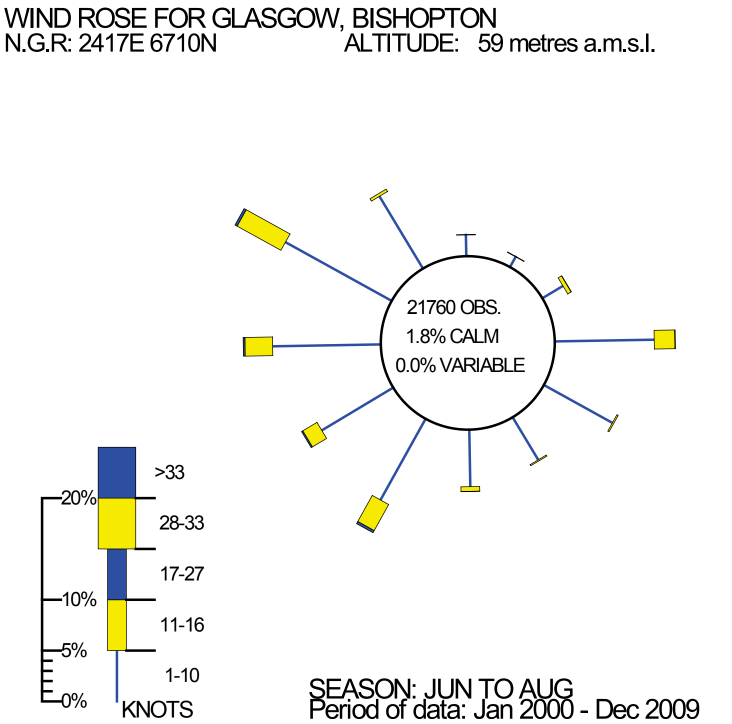


Figure 9.4 Wind rose for Glasgow Bishopton (June to August)

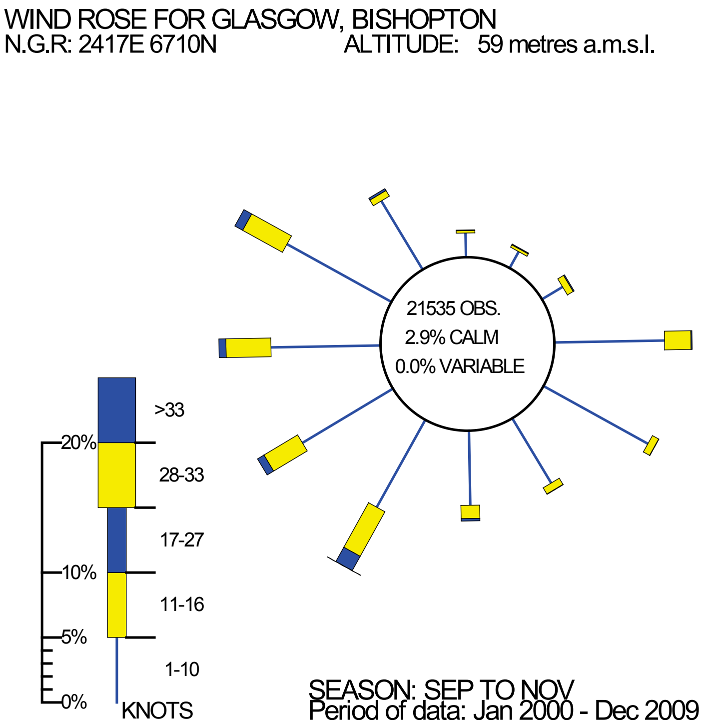


Figure 9.5 Wind rose for Glasgow Bishopton (September to November)

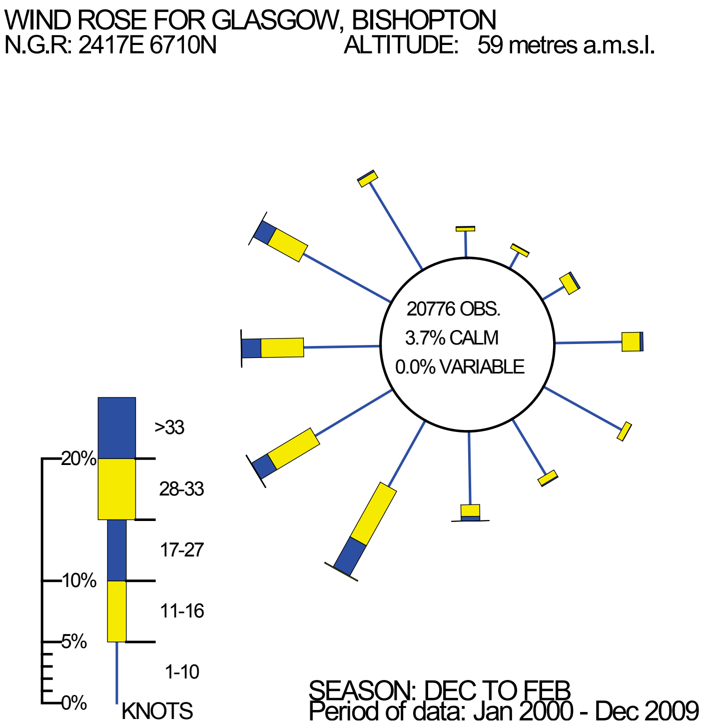


Figure 9.6 Wind rose for Glasgow Bishopton (December to February)

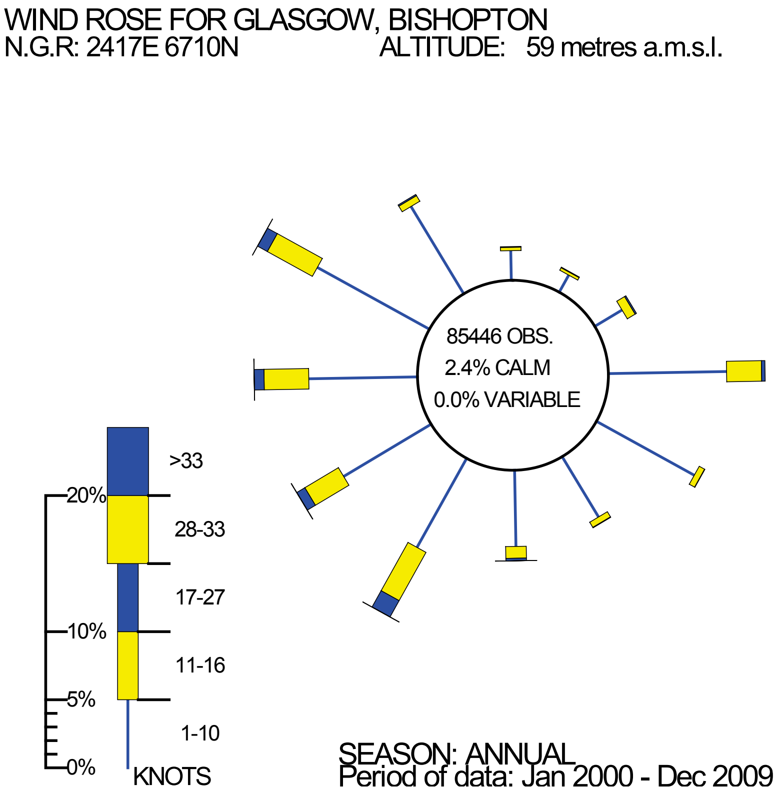


Figure 9.7 Wind rose for Glasgow Bishopton (All year)

Winds are generally lightest in the summer and strongest in the winter. The prevailing wind direction at Glasgow Bishopton is from the south west. Overall patterns appear to be skewed along the east-west axis. There is a higher occurrence of easterly winds during the spring. These directional effects are likely to be due to the local topography at Glasgow Bishopton, and is likely to differ from that at Port Ramsay. The survey data presented in Section 14.2 and Figure 14.7 shows that during one survey period the predominant wind on the north-west side of Lismore was from the north-west, while during the other survey period it was from the south-west.

Winds typically 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 may significantly alter the pattern of surface currents in the Lynn of Lorne and Loch Linnhe. Strong winds may affect tide height depending on wind direction and local hydrodynamics. A strong wind combined with a spring tide may result in higher than usual tides, which will carry accumulated faecal matter from livestock, in and above the normal high water mark, into the production area. A strong northerly wind will result in increased wave action at the Loch Linnhe oyster site, which may resuspend any organic matter settled in the substrate.

10. Current and historical classification status

Loch Linnhe first received a provisional classification for Pacific oysters in 2001, and its classification history since then is presented in Table 10.1 below.

Table 10.1 Loch Linnhe, Pacific oysters

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	a	a	a	a	a	a	a	a	a	a	a	a
2002	A	A	A	A	A	A	A	A	A	A	A	B
2003	A	A	A	A	A	A	A	A	A	A	A	A
2004	A	A	A	A	A	B	B	B	A	A	A	A
2005	A	B	B	B	B	B	B	B	B	A	A	A
2006	A	A	A	A	A	A	B	B	B	A	A	A
2007	A	A	A	A	A	B	B	B	B	A	A	A
2008	A	A	A	A	A	A	B	B	B	B	A	A
2009	A	A	A	B	B	B	B	B	B	A	A	A
2010	A	A	A	B	B	B	B	B	B	A	A	A
2011	A	A	A									

Lower case denotes provisional classification

For all but two years, the production area has held B classification in at least one month. From 2004 onward, months with B classification have tended to occur during the summer months. The only months with no B classifications were January and November.

11. Historical *E. coli* data

11.1 Validation of historical data

All *E. coli* results for samples of Pacific oysters taken from Loch Linnhe from the beginning of 2002 up to the 13th May 2010 were extracted from the database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. This data was used for the statistical analyses with respect to environmental factors. Additional results for samples collected up to 17th February 2011 were incorporated for the data summary presented in Table 11.1 and the geographical and temporal summaries presented in Figures 11.1 and 11.2.

One sample did not have an *E. coli* result recorded against it and was not considered further. The reported location of all other samples fell within the production area, or within 100 m of it. All samples were received by the testing laboratory within two days of collection. Fourteen samples (ten prior to 14th May 2010) had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation. One sample had a reported result of >18000 and this was assigned a nominal value of 36000 for the same purposes.

All *E. coli* results were reported as most probable number per 100g of shellfish flesh and intravalvular fluid.

11.2 Summary of microbiological results

A summary of the sampling is presented in Table 11.1 and a summary of the results is presented in Table 11.2.

Table 11.1 Summary of historical sampling

Sampling Summary	
Production area	Loch Linnhe
Site	Loch Linnhe
Species	Pacific oysters
SIN	AB-172-047-13
Location	40 locations
Total no of samples	109
No. 2002	13
No. 2003	12
No. 2004	11
No. 2005	10
No. 2006	11
No. 2007	9
No. 2008	11
No. 2009	13
No. 2010	17
No. 2011	2

Table 11.2 Summary of historical results

Results Summary	
Minimum	<20
Maximum	>18000
Median	110
Geometric mean	107
90 percentile	550
95 percentile	1100
No. exceeding 230/100g	26 (24%)
No. exceeding 1000/100g	7 (6%)
No. exceeding 4600/100g	2 (2%)
No. exceeding 18000/100g	1 (1%)

11.3 Overall geographical pattern of results

More than half of the samples (63 out of 109) were recorded as having been taken at a single location (NM 876 455), the nominal RMP. This included a proportion of the samples taken up to, and including, 2010. A small number of samples were recorded as having been taken from other locations prior to 2008, each recorded to 100 m accuracy. From 2008 on, most, but not all, samples were reported to better than 10 m accuracy, implying that the sampling locations had been recorded using a GPS at the time of sampling. Figure 11.1 presents a map of those *E. coli* results by reported sampling location.

The recorded sampling locations fell into two loose clusters, one towards the low water mark, and one towards the high water mark. Both clusters were located in the vicinity of a promontory in the centre of the bay at Port Ramsay. One sample (not shown on the map) plotted about 1 km due west of the locations plotted and had a result of 790 *E. coli* MPN/100g. The geometric mean result was slightly lower around the low water mark (96 *E. coli* MPN/100g) than at the high water mark (154 *E. coli* MPN/100g) whereas the proportion of results of over 230 *E. coli* MPN/100g was slightly higher at the low water mark (32% compared to 24%). Neither of these differences was statistically significant (T-test, p=0.506; Fisher's exact, p=0.72; Appendix 6). The highest result, >18,000 *E. coli* MPN/100 g, was recorded from a location within the high water mark cluster. The next highest result (at 1100 *E. coli* MPN/100 g) for which an accurate grid reference was recorded, was reported from a location within the low water mark cluster.

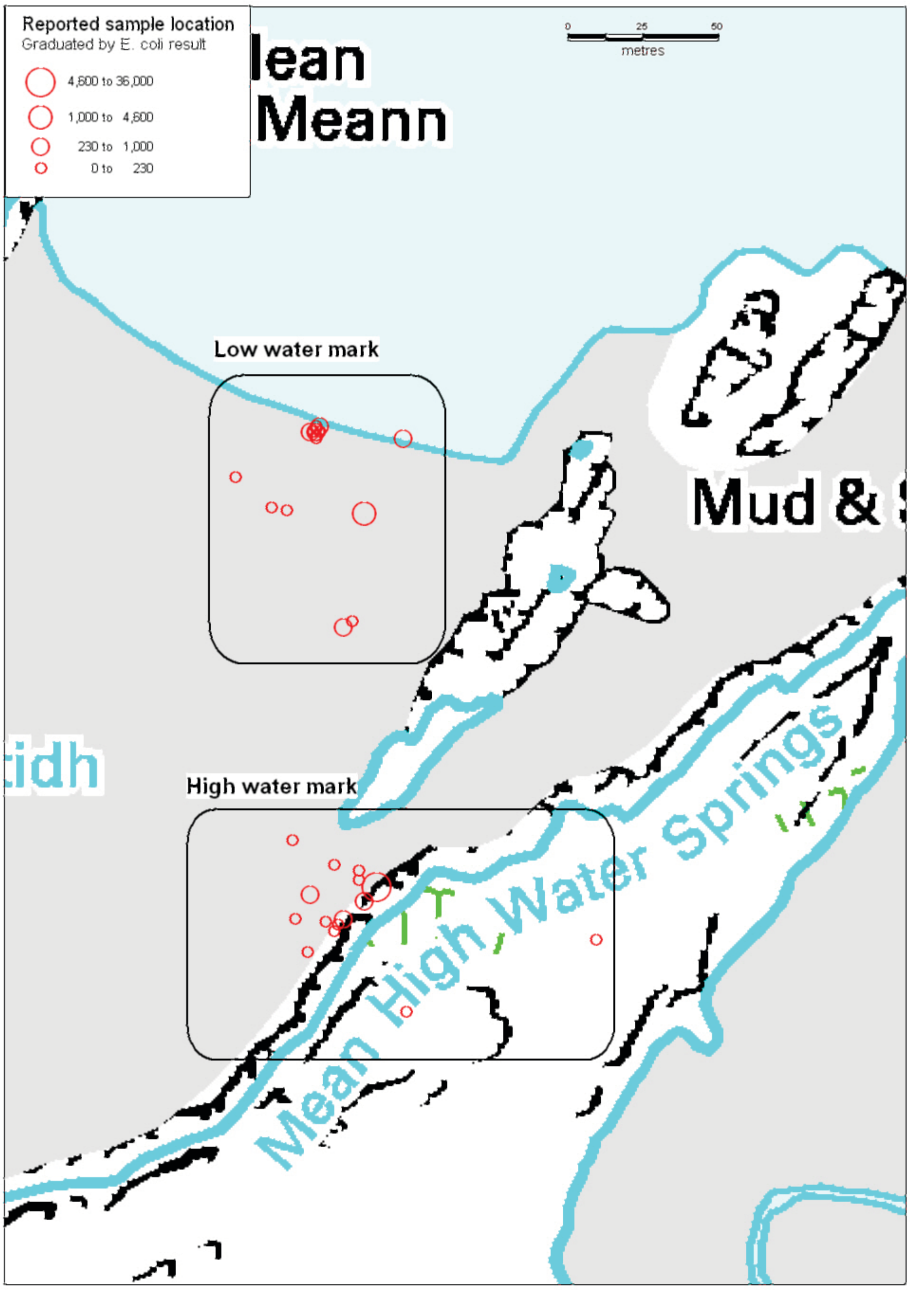


Figure 11.1 Map of *E. coli* results by reported sampling location

11.4 Overall temporal pattern of results

Figure 11.2 presents a scatter plot of individual results against date, fitted with a loess trend line. 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. These trend lines help to highlight any apparent underlying trends or cycles.

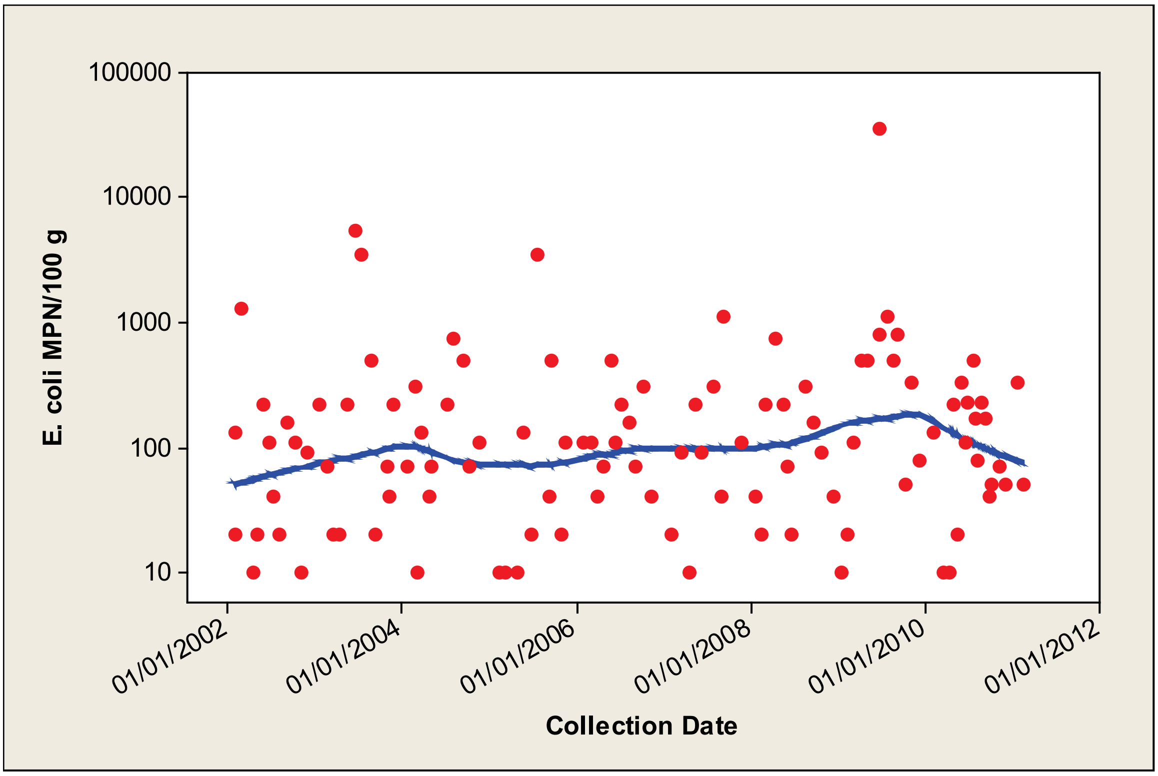


Figure 11.2 Scatterplot of *E. coli* results by date with loess line

No overall trends or cycles are apparent in Figure 11.2.

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 for Loch Linnhe oysters, with loess lines to highlight any trends.

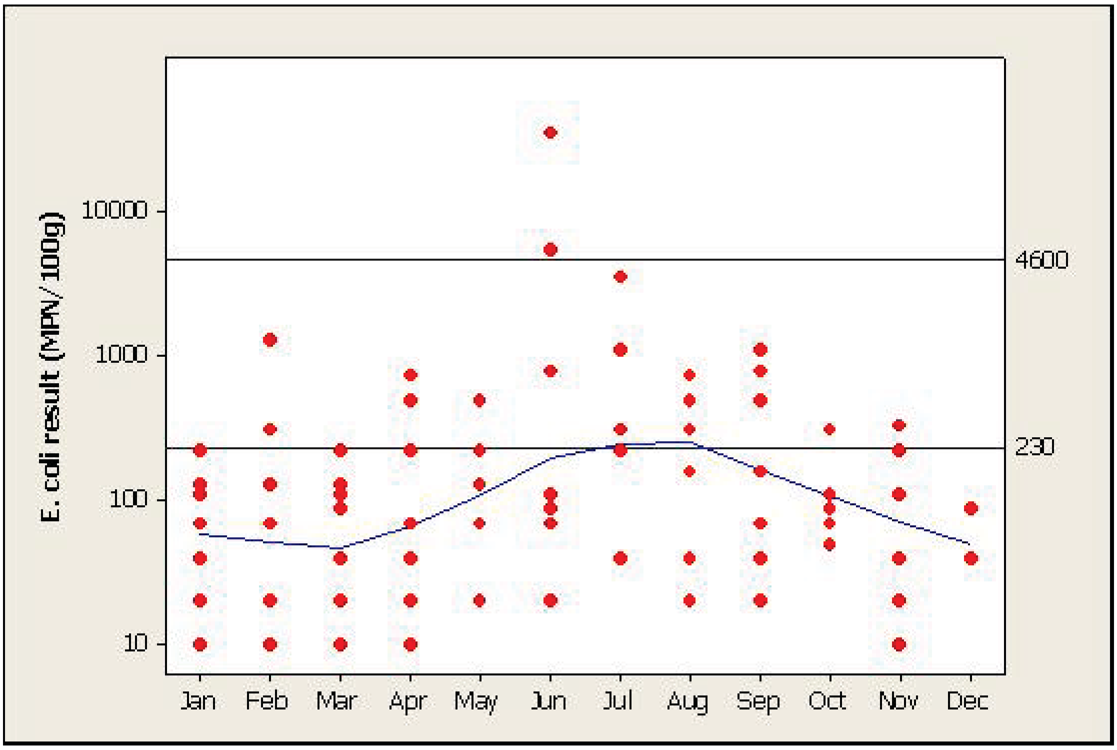


Figure 11.3 Scatterplot of results by month

Results were generally higher during the warmer months of the year. Both results greater than 4,600 *E. coli* MPN/100 g arose during June.

For statistical evaluation, seasons were split into spring (March - May), summer (June - August), autumn (September - November) and winter (December - February). Figure 11.4 shows a boxplot of *E. coli* result by season.

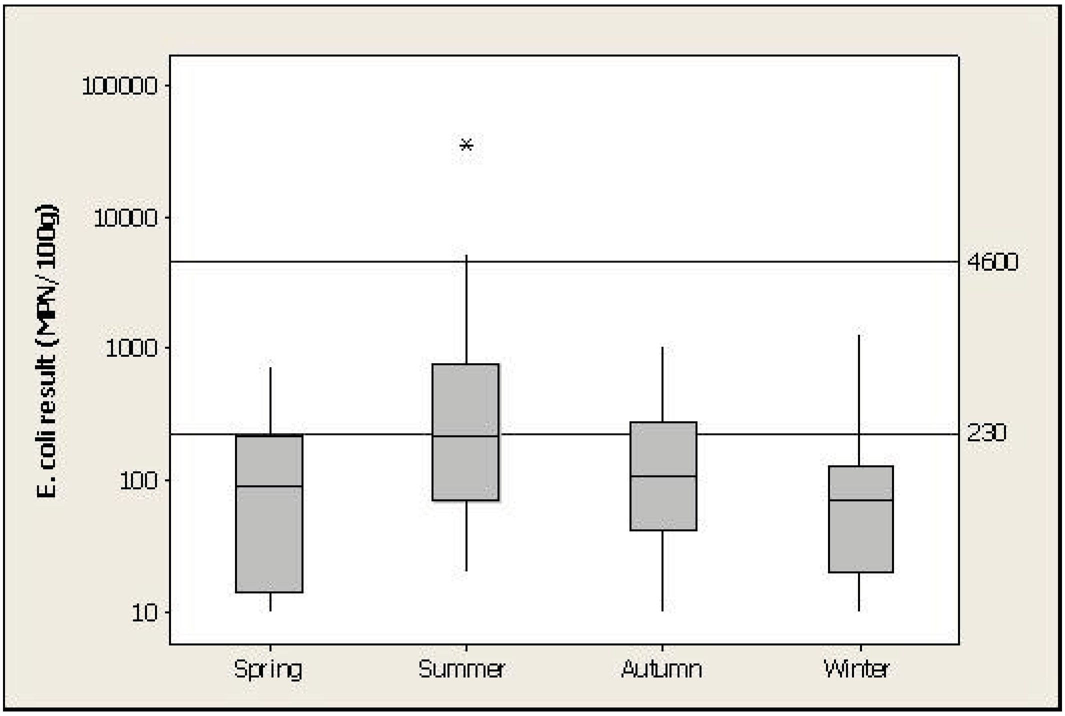


Figure 11.4 Boxplot of result by season

A significant difference was found between results by season (One-way ANOVA, p=0.003, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicates that results for the summer were significantly higher than those for the spring and winter.

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 weather station is at Lismore: Frackersaig Farm, about 5 km to the southwest of the two production areas. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2009 (total daily rainfall in mm). Figure 11.5 presents a scatterplot of *E. coli* results against rainfall in the previous two days. Spearman's Rank correlations were carried out between results and rainfall.

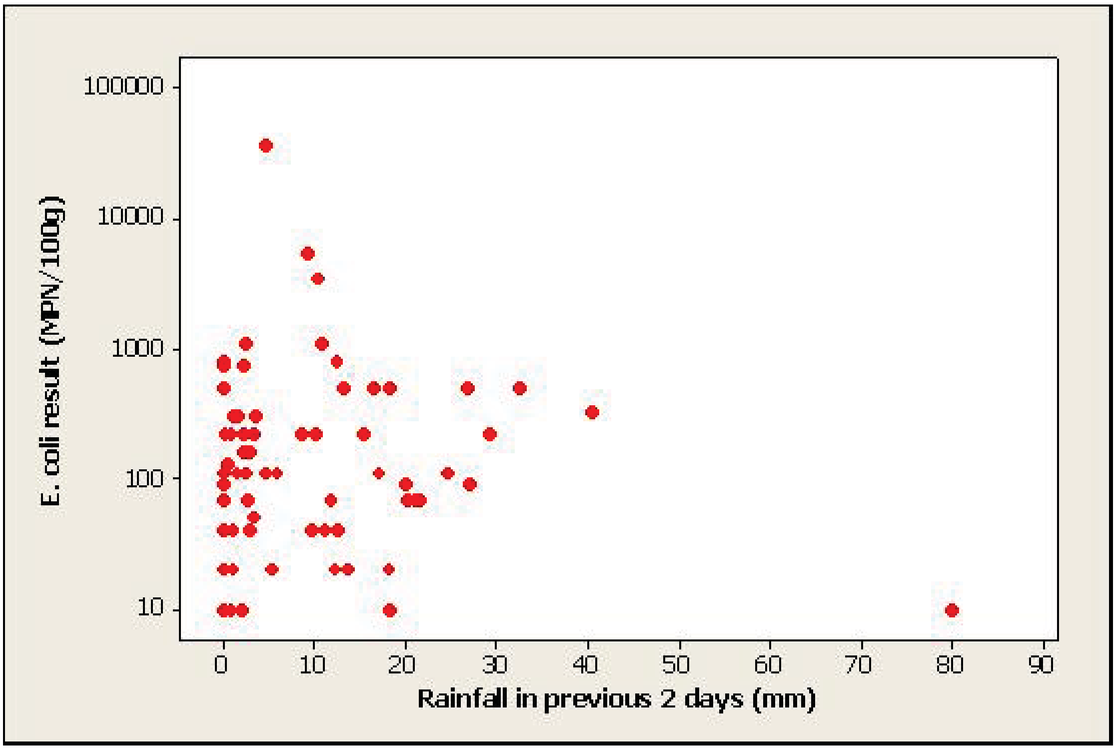


Figure 11.5 Scatterplot of result against rainfall in previous 2 days

No significant correlation was found between *E. coli* result and rainfall in the previous 2 days for (Spearman's rank correlation=0.132, p>0.10, Appendix 6).

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. The scatterplot is shown in Figure 11.6.

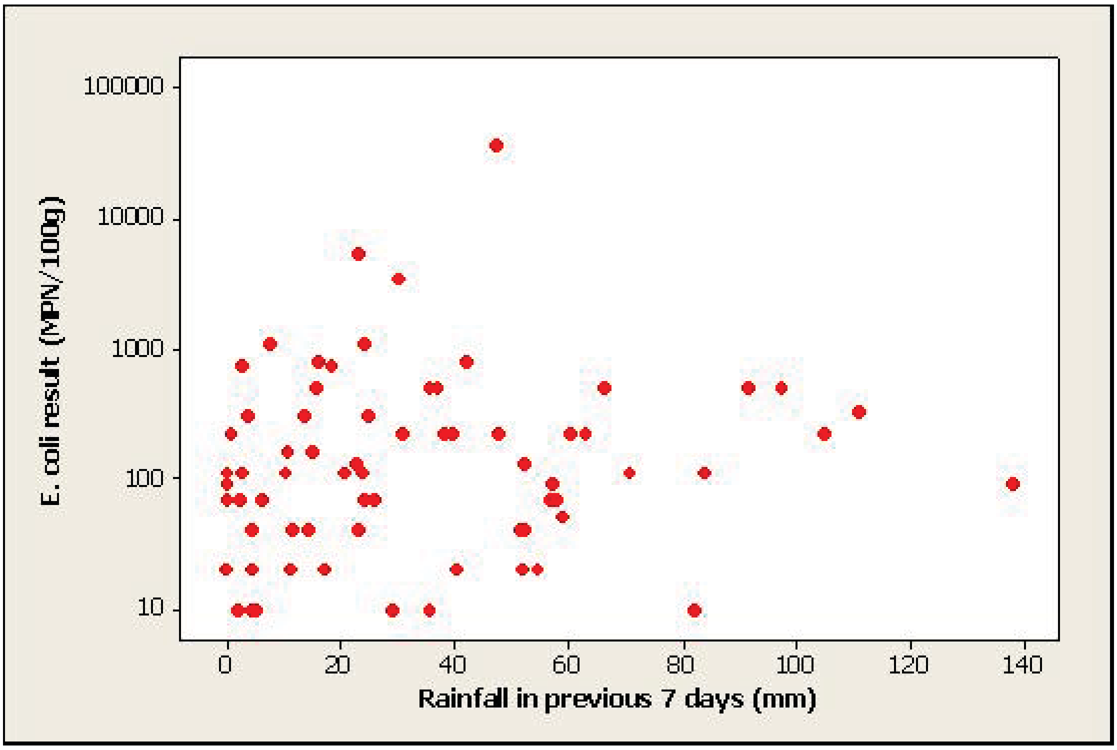


Figure 11.6 Scatterplot of result against rainfall in previous 7 days

A significant positive correlation was found between *E. coli* result and rainfall in the previous 7 days (Spearman's rank correlation=0.204, $p<0.05$, Appendix 6).

11.6.2 Analysis of results by tidal height and state

Spring/Neap tidal cycle

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 start about 2 days after the full/new moon, and last approximately 3 or 4 days (centred at about 45º on the plot). The tides then decrease to the smallest (neap tides; centred at about 225º) and then increase back to spring tides. Results less than 230 *E. coli* MPN/100g are plotted in green, those between 230 and 1000 *E. coli* MPN/100g are plotted in yellow, and those over 1000 *E. coli* MPN/100g are plotted in red. 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.

No significant correlation was found between *E. coli* results and the spring/neap cycle (circular-linear correlation, r=0.122, p=0.262 Appendix 6). Sampling was targeted towards spring tides.

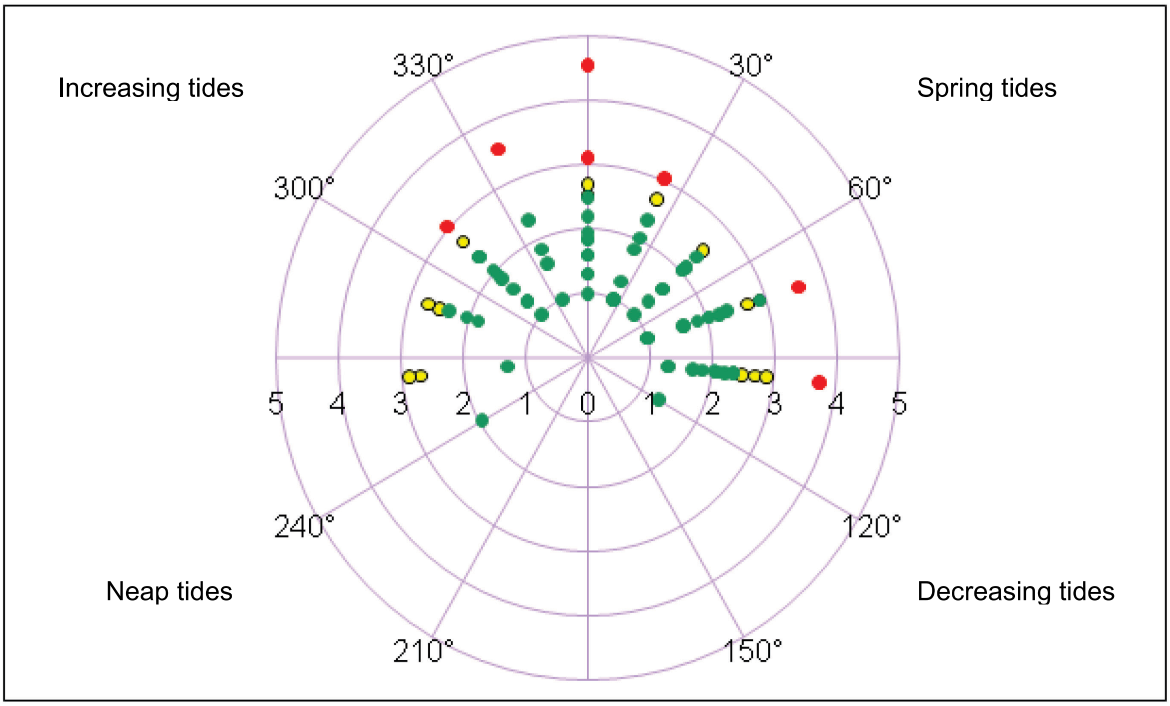


Figure 11.7 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle

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 is at 180º. Results less than 230 *E. coli* MPN/100g are plotted in green, those between 230 and 1000 *E. coli* MPN/100g are plotted in yellow, and those over 1000 *E. coli* MPN/100g are plotted in red.

No significant correlation was found between *E. coli* results and the high/low tidal cycle (circular-linear correlation, r=0.103, p=0.384, Appendix 6). Sampling was targeted towards ebb and low tides although was recorded as having been undertaken on other states on a proportion of occasions.

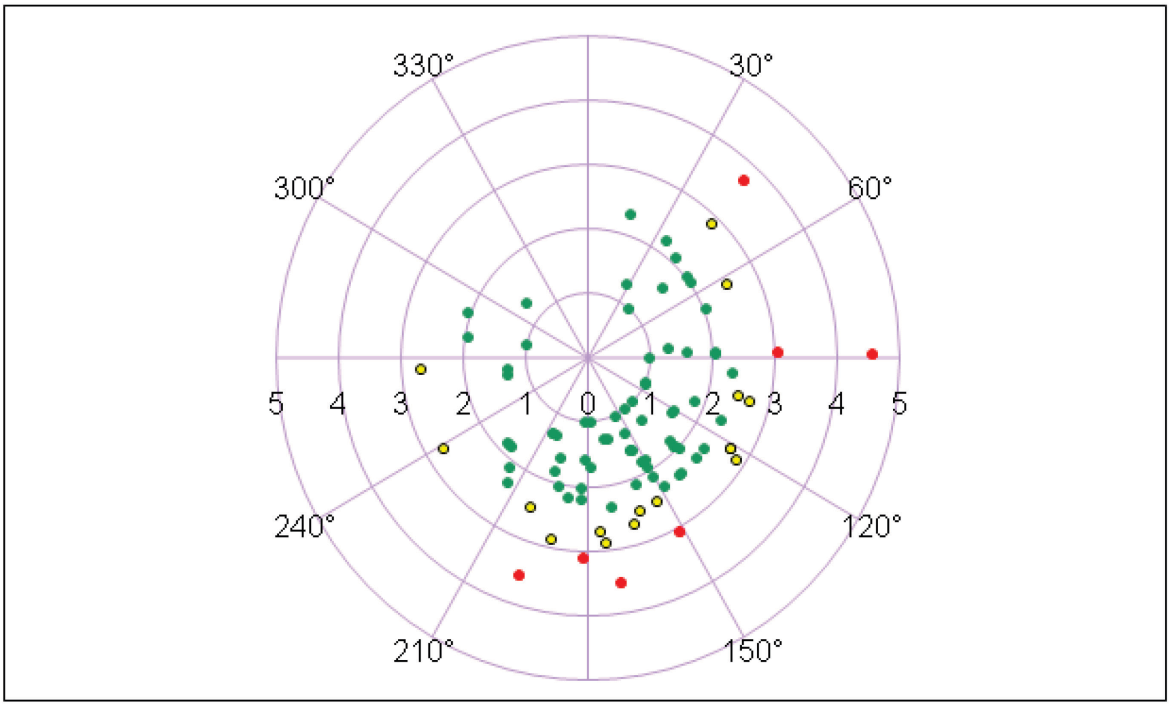


Figure 11.8 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle

11.6.3 Analysis of results by 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 presents a scatterplot of *E. coli* results against water temperature.

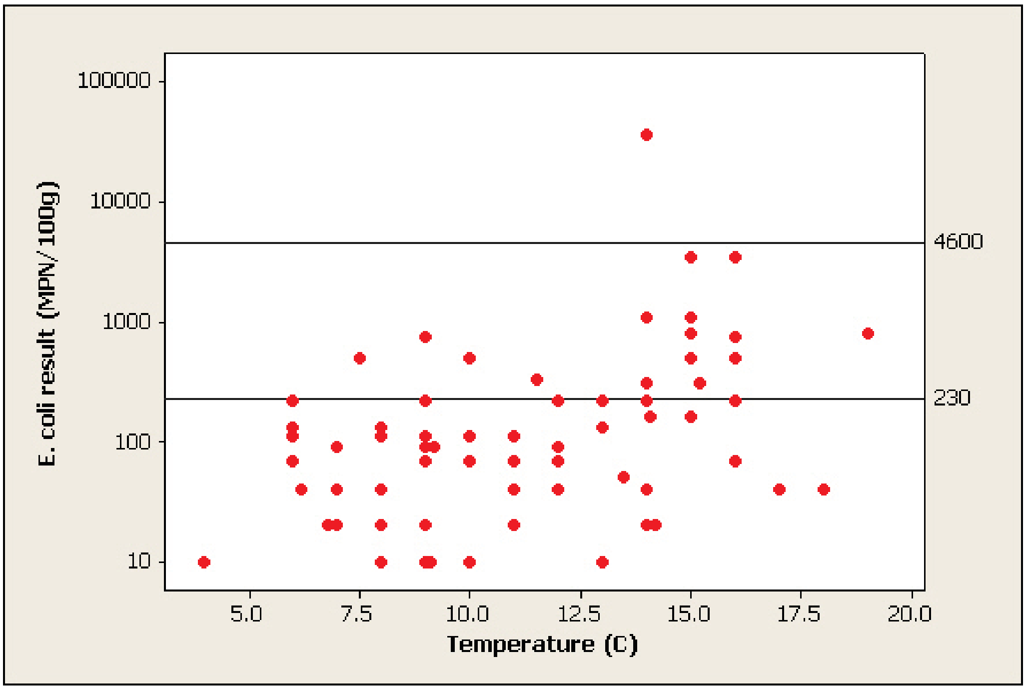


Figure 11.9 Scatterplot of result by water temperature

A significant positive correlation was found between *E. coli* result and water temperature (Spearman's rank correlation= 0.418, p<0.0005, Appendix 6).

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. Figures 11.10 presents a scatter plot of *E. coli* result against salinity.

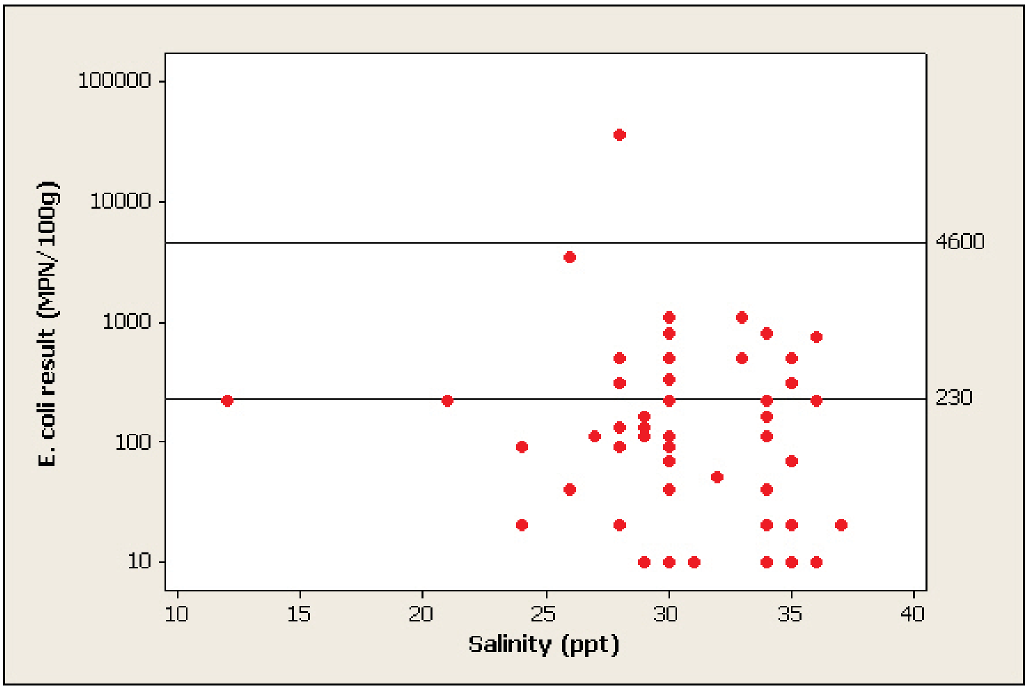


Figure 11.10 Scatterplot of result by salinity

No significant correlation was found between the *E. coli* result (Spearman's rank correlation= -0.114, p>0.10, Appendix 6).

11.7 Evaluation of peak results

A total of 7 Pacific oyster samples gave results greater than 1000 *E. coli* MPN/100g, details of which are presented in Table 11.2. Of the high results, one arose in February, two in June, three in July and on in September and so were centred around the warmer months. Water temperature, where recorded was 14 °C or higher. They were taken from a variety of locations, with the earlier four samples attributed to the RMP. The high results all occurred after recent rainfall, although the amounts varied markedly. The samples were taken under a variety of tidal conditions.

Table 11.3 Historic *E. coli* sampling results over 1000 *E. coli* MPN/100g

Collection date	Site	Species	*E. coli* (MPN/ 100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tidal state (high/ low)	Tidal state (spring/ neap)
27/02/2002	Loch Linnhe	Pacific oysters	1300	NM 876 455	*	*	*	*	Low	Spring
18/06/2003	Loch Linnhe	Pacific oysters	5400	NM 876 455	9.3	23	*	*	High	Decreasing
16/07/2003	Loch Linnhe	Pacific oysters	3500	NM 876 455	*	*	16	*	Low	Spring
20/07/2005	Loch Linnhe	Pacific oysters	3500	NM 876 455	10.3	30.3	15	26	Low	Increasing
10/09/2007	Loch Linnhe	Pacific oysters	1100	NM 87608 45341	2.5	7.6	14	30	Ebb	Increasing
22/06/2009	Loch Linnhe	Pacific oysters	>18000	NM 87620 45354	4.6	47.5	14	28	Ebb	Spring
23/07/2009	Loch Linnhe	Pacific oysters	1100	NM 87616 45478	10.9	24.2	15	33	Low	Spring

* Data unavailable

11.8 Summary and conclusions

The samples taken when positions were accurately recorded by GPS loosely fall into two clusters, one towards the low water mark, and one towards the high water mark. The geometric mean result was slightly lower around the low water mark whereas the proportion of results of over 230 *E. coli* MPN/100g was higher at the low water mark but neither of these differences was statistically significant.

No overall trends in levels of contamination were found from 2002 to 2010. A significant seasonal effect was found, with results for the summer significantly higher than those for the spring and winter. A strong positive correlation was also found between *E. coli* results and water temperature.

No significant correlation was found between *E. coli* results and rainfall in the previous 2 days, but a weak correlation was found between *E. coli* results and rainfall in the previous 7 days. All results >1,000 *E. coli* MPN/100 g occurred after recent rainfall although the amount, where available, varied markedly. No correlation was found between *E. coli* results and salinity at the time of collection. The latter indicates that, if contamination was associated with freshwater sources, this had either occurred at a point in time sufficiently remote for the salinity to have changed by the time of sampling, or that the sea and freshwater had mixed well and the proportion of freshwater at the trestles was small.

No significant correlation was found between levels of *E. coli* in shellfish and tidal state on either the spring/neap or high/low tidal cycles, although sampling was generally targeted towards low water on the larger tides.

It should be noted that the relatively small amount of data precluded the assessment of the effect of interactions between environmental factors on the *E. coli* concentrations in shellfish.

11.9 Sampling frequency

When a production area has held the same (non-seasonal) classification for 3 years, and the geometric mean of the results falls within a certain range it is recommended that the sampling frequency be decreased from monthly to bimonthly. This is not appropriate for the Loch Linnhe production area as it has held a seasonal classification within the last three years.

12. Designated Shellfish Growing Waters Data

The Port Ramsay area is covered by the Lismore designated shellfish growing water. The designation was made in 2002 and monitoring started in 2003. The designated area is described as: “An area south of a line between NM8722146000 and NM8878146000, and extending to MLWS.”. The associated sampling point is given by SEPA as: NG 37680 32133. The extent of the designation, and location of the sampling point, is shown in Figure 12.1.

Under the Shellfish Waters Directive (European Communities, 2006), designated waters must be monitored quarterly for faecal coliforms in the shellfish flesh and intervalvular fluid. The Directive includes a guideline value of 300 faecal coliforms in 75% of samples. The minimum specified sampling frequency is quarterly.

Monitoring of shore mussels at Lismore started in the third quarter of 2003. The faecal coliform results are presented in Table 12.1. The results were reported against the designated monitoring point: NM 87900 45600. From 2007, SEPA started to use the FSAS *E. coli* data for determining compliance for most shellfish waters and this included Lismore. A review of those *E. coli* results will have been included in Section 11 and so will not be presented in this section.

Table 12.1 SEPA faecal coliform results (faecal coliforms /100 g) for shore mussels gathered from Lismore

Year	Quarter	OS Grid Ref.
		NM 8790 4560
2003	**Q3**	310
	Q4	70
2004	**Q1**	220
	Q2	2400
	Q3	500
	Q4	220
2005	**Q1**	40
	Q2	2800
	Q3	320
	Q4	55
2006	**Q1**	135
	Q2	190
	Q3	11000
	Q4	-
2007	**Q1**	360

The results show that at least intermittent significant levels of faecal contamination occur in shore mussels in the vicinity of Port Ramsay. The mussel results were of the same order as those seen in the Pacific oysters within the bay: the SEPA monitoring point was located approximately 300 m from the current oyster trestles. Highest results in the mussels occurred during the second or third quarter of the year, a similar pattern to that seen with *E. coli* in the Pacific oysters.

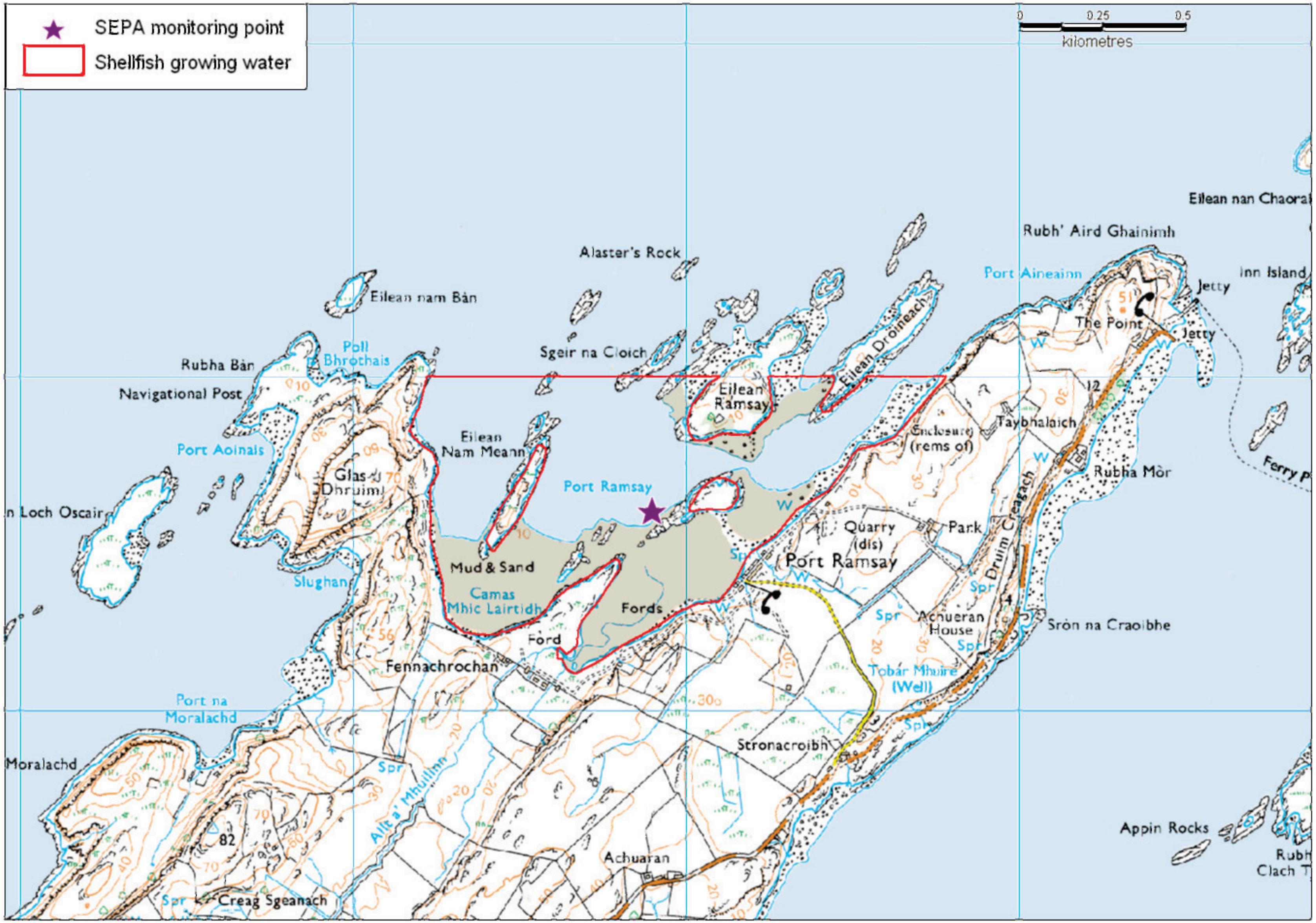


Figure 12.1 Designated Shellfish Growing Water and monitoring point

13. River Flow

The gauging stations on watercourses entering Loch Linnhe are located at the head of the Loch, more than 30 kilometres from the oyster farm at Port Ramsay. These sources were therefore not taken into account with regard to the present sanitary survey.

The watercourses listed in Table 13.1 were measured and sampled during the shoreline survey. There were rain showers on the day of the survey. The sampling locations are shown on the map presented in Figure 13.1. 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 x 10^3, in digital format it is written as 1E+3.

Table 13.1 Watercourse loadings for Port Ramsay

No	Grid Reference	Description	Width (m)	Depth (m)	Flow (m/s)	Flow in m^3/day	*E.coli* (cfu/ 100ml)	Loading (*E.coli* per day)
1	NM 88461 45668	Stream	0.4	0.03	0.146[1]	151	30	$4.5x10^7$
2	NM 88226 45468	Stream	0.65	0.05	0.195[1]	548	900	$4.9x10^9$
3	NM 88169 45382	Stream	0.4	0.04	0.004[1]	6	110	$6.1x10^6$
4	NM 88148 45336	Stream	Not measured			-	740000	-
5	NM 88109 45316	Stream	0.8	0.1	0.029[1]	200	60	$1.2x10^8$
6	NM 87837 45187	Small stream	Not measured			-	1000	-
7	NM 87798 45175	Stream	Not measured			-	1000	-
8	NM 87611 45172	Stream	0.5	0.5	0.248[1]	5357	220	$1.2x10^{10}$

[1]Average of two separate readings

Calculated loadings were low to moderate. Three of the streams were too small to measure. This meant that the loadings could not be estimated. One of the three, No. 4 in Table 13.1, had a very high *E. coli* concentration. The stream was below a number of septic tanks and it was noted that there was a strong smell of sewage and abundant sewage fungus present.

The watercourses all lie to the east of the present oyster farm and, under conditions where currents flowed towards the farm, would be expected to affect the water quality at that location, with the greatest potential impact on the northern and eastern sides.

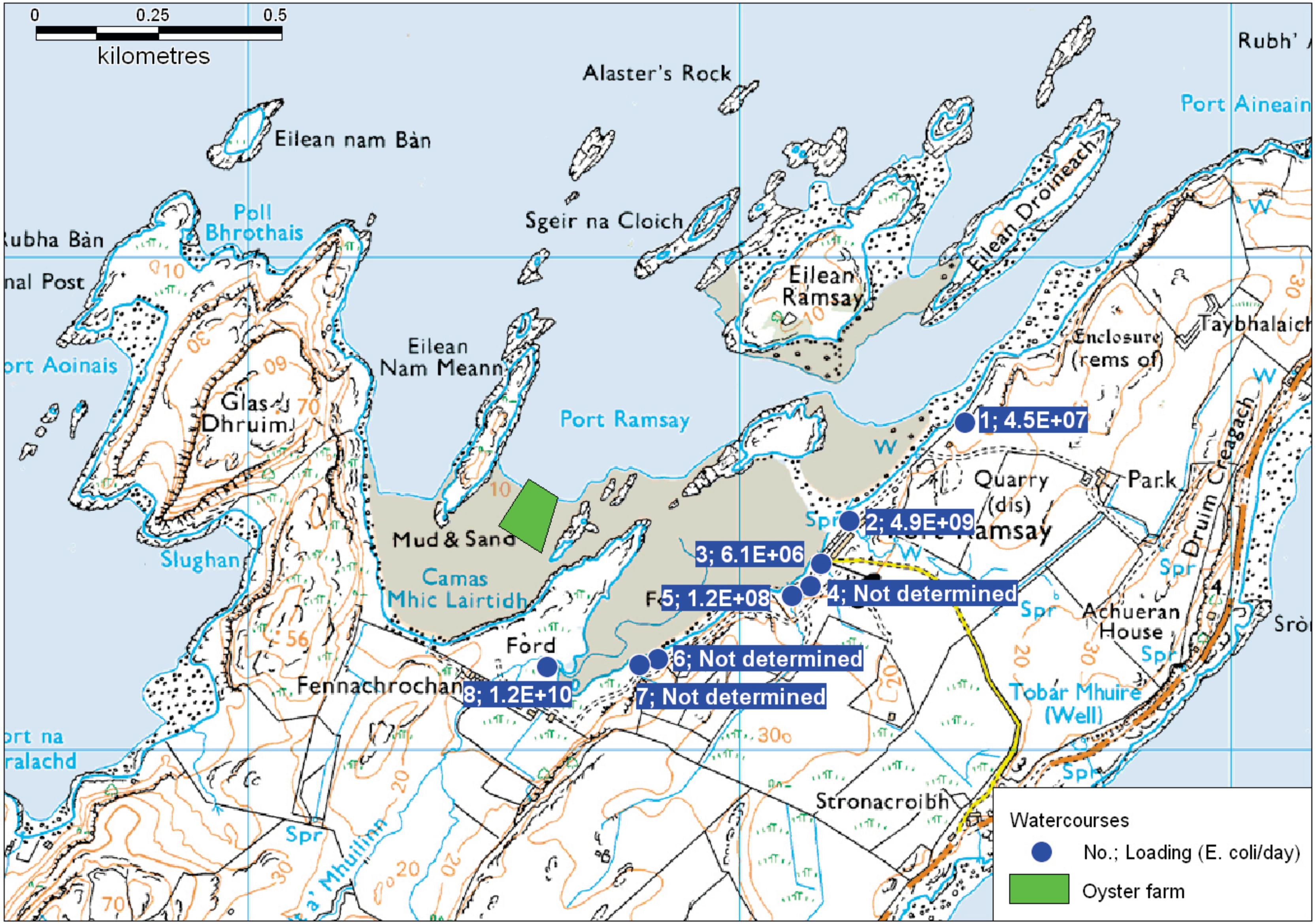


Figure 13.1 Map of stream loadings at Port Ramsay

14. Bathymetry and Hydrodynamics

The OS map and Hydrographic Chart for the Port Ramsay area are shown in Figures 14.1 and 14.2 respectively.

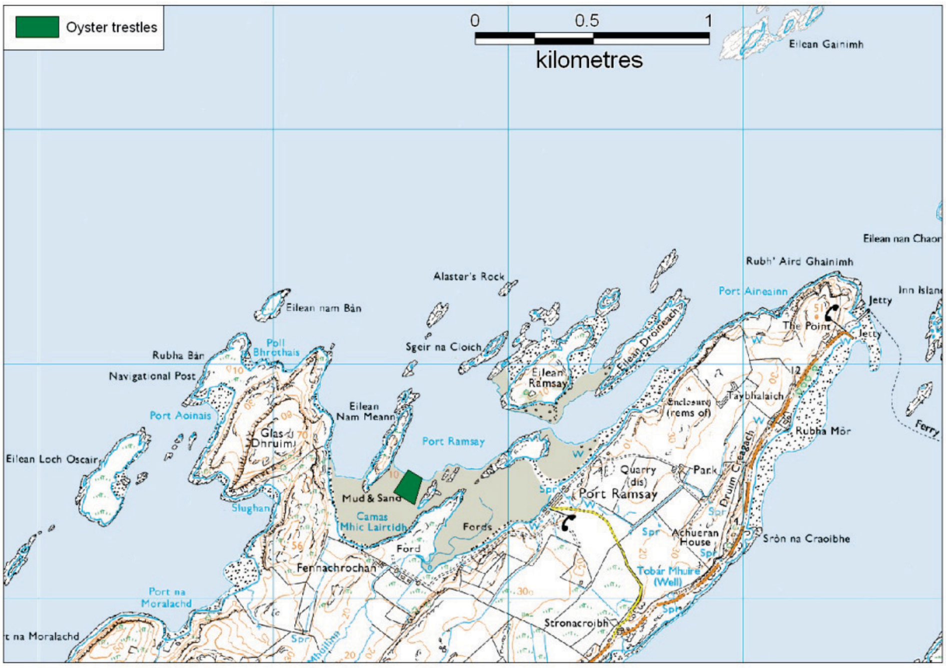


Figure 14.1 OS map of Port Ramsay

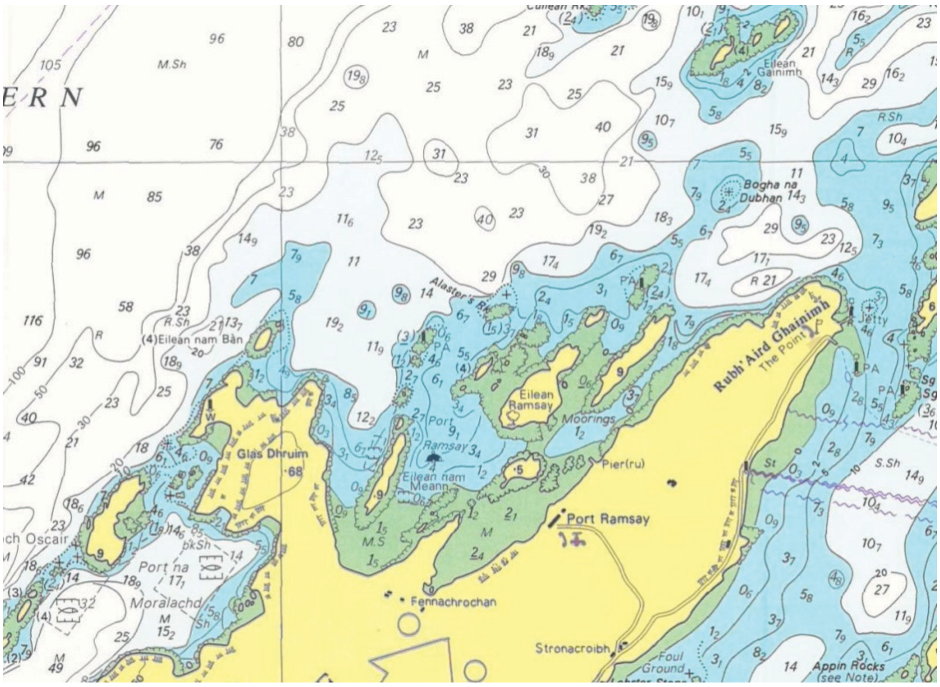


Figure 14.2 Bathymetry at Port Ramsay

Port Ramsay is located at the north end of the island of Lismore. Lismore itself is located in Loch Linnhe, with the Lynn of Lorne lying between Lismore and the mainland on the eastern side and the Lynn of Morvern lying between Lismore and the mainland on the western side. The oyster trestles are located on a drying area on the south-west side of the bay, immediately to the east of Eilean Nam Meann. Past the drying area, depths increase fairly rapidly to over 9 m in the middle of the bay. There are several other islands in Port Ramsay, the larger of these being located on the eastern side of the bay. Outside of Port Ramsay, the seabed shelves further towards the main channel of the Lynn of Morvern, where the depth exceeds 100 m in places.

14.1 Tidal Curve and Description

The two tidal curves below are for Port Appin, approximately 3.5 km from the oyster farm. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 BST on 09/09/10 and the second is for seven days beginning 00.00 BST on 16/09/10. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle, including the dates of the shoreline survey.

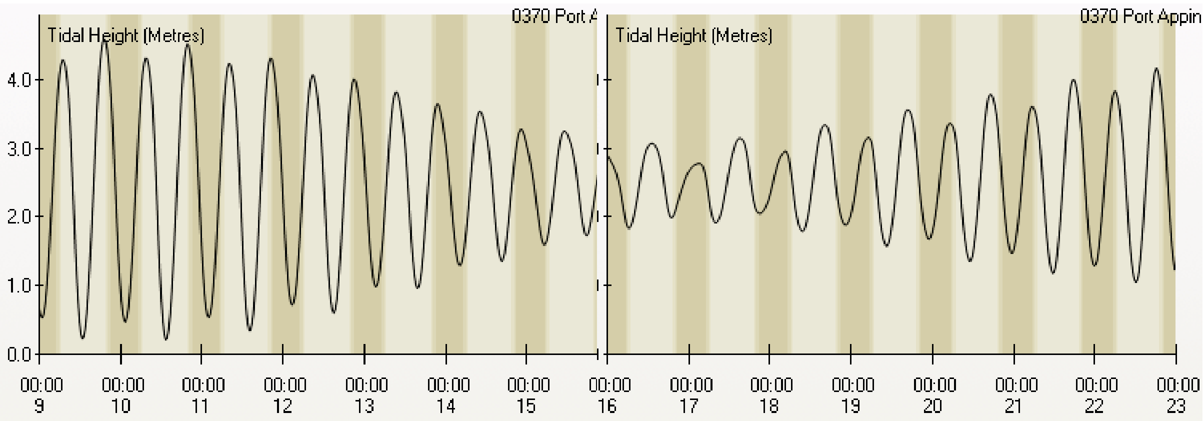


Figure 14.3 Tidal curves for Port Appin

The following is the summary description for Port Appin from TotalTide:

0370 Port Appin is a Secondary Non-Harmonic port. The tide type is Semi-Diurnal.

HAT	4.7 m
MHWS	4.2 m
MHWN	3.1 m
MSL	2.35 m
MLWN	1.9 m
MLWS	0.8 m
LAT	0.1 m

Predicted heights are in metres above Chart Datum. The tidal range at spring tide is 3.4 m, and at neap tide 1.2 m, and so tidal ranges in the area are moderate.

14.2 Currents

Tidal stream information was available for several stations in Loch Linnhe: one of these was located approximately 4 km NNE of the oyster farm, immediately west of the Isle of Shuna. The location of this station, together with the tidal streams for peak flood and ebb tide, are presented in Figures 14.4 and 14.5, and the tidal diamond is presented in Table 14.1.

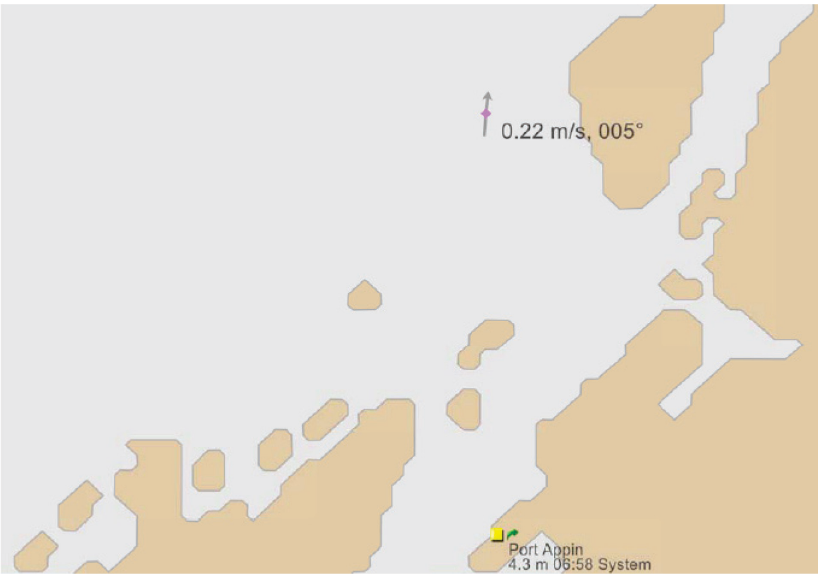


Figure 14.4 Spring flood tide in Loch Linnhe

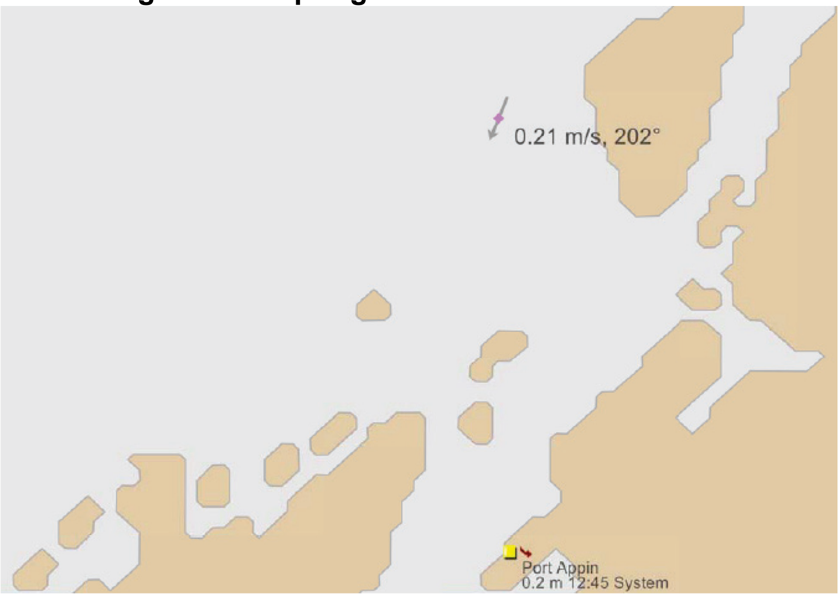


Figure 14.5 Spring ebb tide in Loch Linnhe

Table 14.1 Tidal streams for station SN037F (56°35.10'N 5°25.10'W) (taken from Totaltide)

Time	Direction	Spring rate (m/s)	Neap rate (m/s)
-06h	169°	0.10	0.05
-05h	140°	0.05	0.00
-04h	017°	0.10	0.05
-03h	015°	0.15	0.05
-02h	005°	0.21	0.10
-01h	008°	0.10	0.05
HW	034°	0.05	0.05
+01h		0.00	0.00
+02h	225°	0.05	0.05
+03h	219°	0.10	0.05
+04h	202°	0.21	0.05
+05h	194°	0.15	0.05
+06h	180°	0.10	0.05

Tidal streams at the station are largely bidirectional but weak. This is in accordance with the statement in the Clyde Cruising Club sailing direction for the area which identifies that tidal streams within Loch Linnhe are generally weak (Clyde Cruising Club, 2007).

SEPA provided data from two current meters at locations in the vicinity of the oyster farm. These were located in the adjacent bay to the south-west of Port Ramsay (Figure 14.6). The survey periods were as given in Table 14.1.

Table 14.2 Survey periods for the current meter studies

Location	NGR	Survey period
Dubh Sgeir	NM 8610 4527	09/05/2000 - 25/05/2000
Port na Moralachd	NM 8664 4541	25/05/2000 - 14/06/2000

Plots of the current directions and speeds at the two locations, together with the wind direction and speeds over the relevant periods, are shown in Figure 14.5.

Mean current speeds at Dubh Sgeir were 6.7 cm/s (near-surface), 4.8 cm/s (mid-depth), and 5.0 cm/s (near-bottom). The highest current speed recorded during the period occurred at near-bottom and was 33 cm/s (0.33 m/s; approximately 0.7 knots). The prevailing current direction differed markedly between the three depths. Near the bottom, the direction was mainly north to north-easterly. At mid-depth, it was generally bidirectional, west to west-north-westerly and east to north-easterly. At the surface, it was strongly bidirectional, north to north-north-westerly and south-south-west to south-westerly. During the period, the strongest winds were from the north-west and this did not appear to be markedly reflected in the direction of the surface current.

Mean current speeds at Port na Moralachd were 2.3 cm/s (near-surface), 2.1 cm/s (mid-depth) and 2.6 cm/s (near-bottom). The highest current speed recorded during the period occurred at near-bottom and was 14 cm/s (0.14 m/s; approximately 0.3 knots). Current directions at all three depths were more variable than at Dubh Sgeir. At depth, the strongest currents flowed in a westerly direction. At mid-depth, they flowed to the north, south, or generally to the east. At the surface, there was no identifiable general direction of flow. During the period, the strongest winds were from the south-west. Again, this did not appear to be markedly reflected in the direction of the surface current.

The currents at the two locations will have been influenced by the shape and aspect of the bay and the presence of nearby islands. The current directions are likely to bear little relationship to those at Port Ramsay, given the different shape and aspect of that bay and the differing relative location and size of islands. However, the weak current speeds recorded should be indicative of those that will occur below mean low water springs at Port Ramsay.

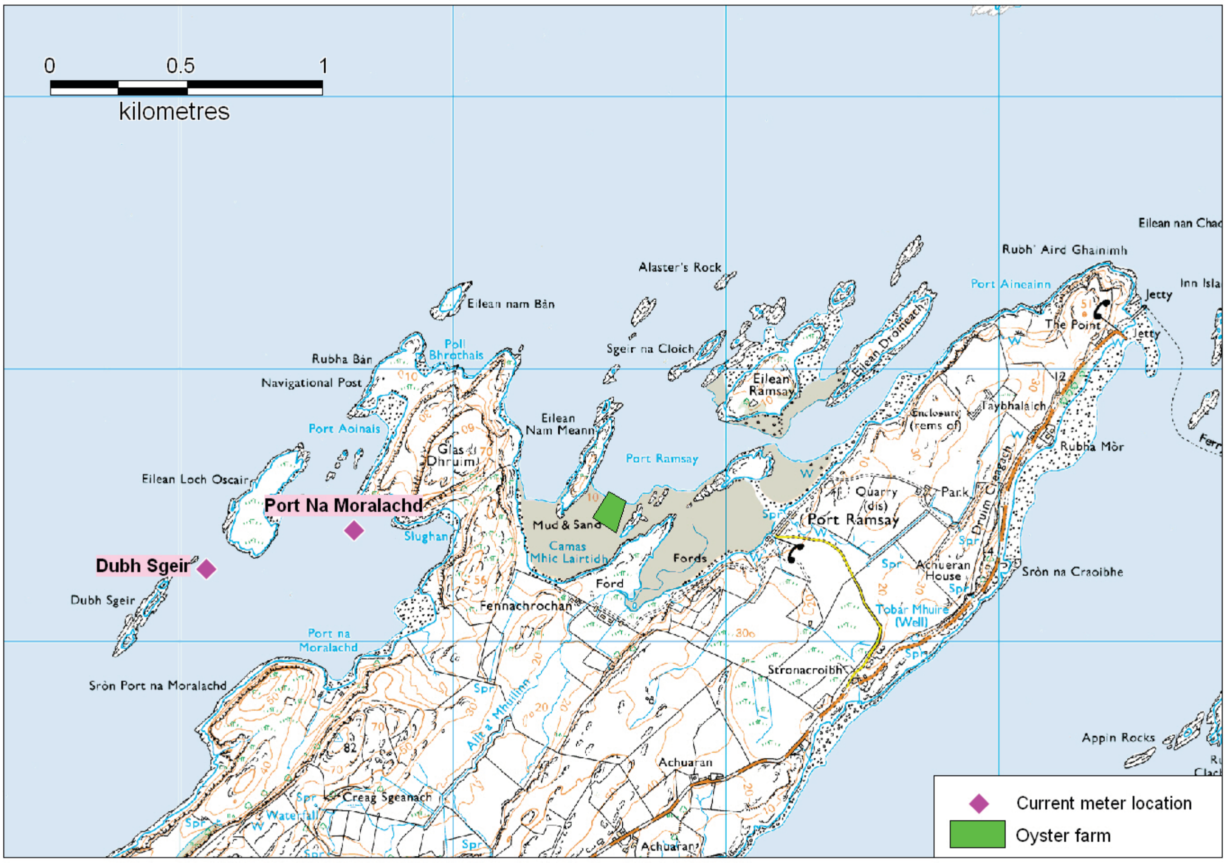


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Figure 14.6 Current meter locations

14.3 Conclusions

The bay at Port Ramsay is shallow and thus dilution of contaminants from local sources will be limited. Depths outside the bay are much greater and this will limit any effects from more distant sources. Current speeds in the area are very low, although these will be greater across the drying areas during mid-flood and mid-ebb tides and also in channels between the islands. The bay will tend to fill from the west during flood tide and empty in that direction during the ebb tide. Water above the oyster trestles will move across the trestles during the ebb, and that from east of the trestles may impact on the outer edge of the present oyster area, the main area of trestles being protected from that direction by a spit of land.

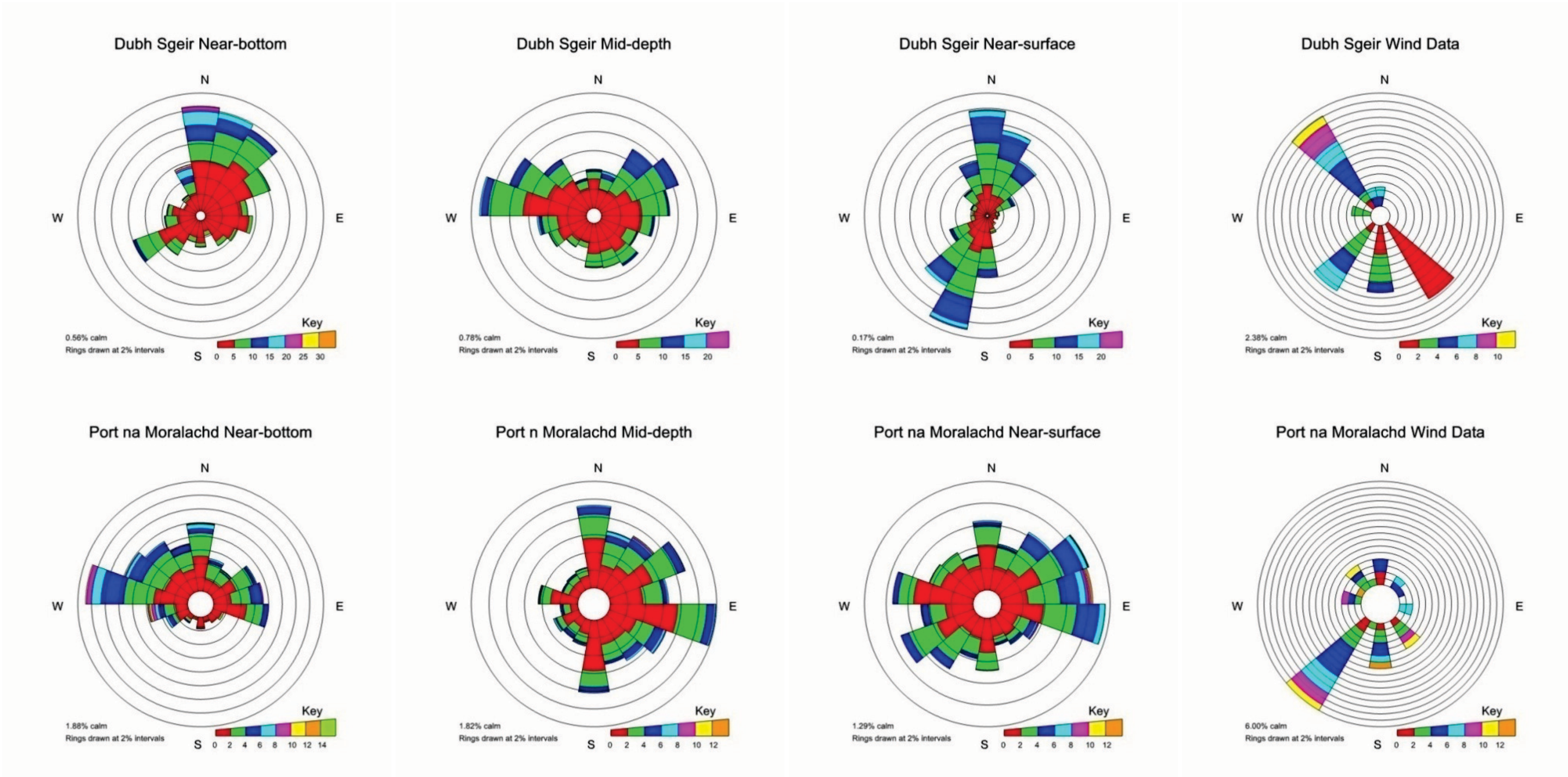

Figure 14.7 Current and wind plots for Dubh Sgeir and Port na Moralachd

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. The blank space in the centre of a plot relates to the proportion of time for which the current or wind was recorded as stationary. Wind speeds were recorded with a hand-held anemometer and the direction estimated.

15. Shoreline Survey Overview

The shoreline survey was conducted on the 9th September 2010 varying weather conditions (dry and sunny in the morning and raining and overcast in the afternoon).

There are approximately 250 oyster trestles at the Loch Linnhe fishery. These oyster trestles are situated on an intertidal area in the centre of Port Ramsay.

There is a small settlement called Port Ramsay located to the east of the fishery. During the shoreline survey a total of nine septic tanks and two outfall pipes were observed in the settlement of Port Ramsay. A fresh water sample was taken from a stream that one of the outfall pipes was discharging into and returned a high result of 900 *E. coli* cfu/100 ml. No sanitary debris was observed during the shoreline survey.

On the far eastern shoreline approximately 10 sheep were observed fenced in a field adjacent to the shoreline and south of the oyster trestles a further 12 sheep were observed fenced off in a field next to a house and adjacent to the shoreline. Approximately 12 sea gulls were observed west of the oyster trestles.

Two seawater samples were taken adjacent to the oyster trestles. Both were had low levels of *E. coli* (10 *E. coli* cfu/100 ml).

Fresh water samples and discharge measurements were taken at all of the streams draining into the survey area. The streams were of varying size and drained areas of rough grassland that had some patches of woodland. All the streams discharged into the eastern side of Port Ramsay. Fresh water samples collected from the streams contained varying levels of contamination (30 to 740000 *E. coli* cfu/100 ml). The stream with the highest *E. coli* result of 740000 (*E. coli* cfu/100 ml) was located below some septic tanks and had a strong odour and sewage fungus present in it.

Oyster samples were collected from three separate oyster trestles. The two samples taken at the north-west and south-west corners of the trestles had results of 130 *E. coli* MPN/100 g. The oyster sample taken in the middle of the trestles had a result of 170 *E. coli* MPN/100 g.

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

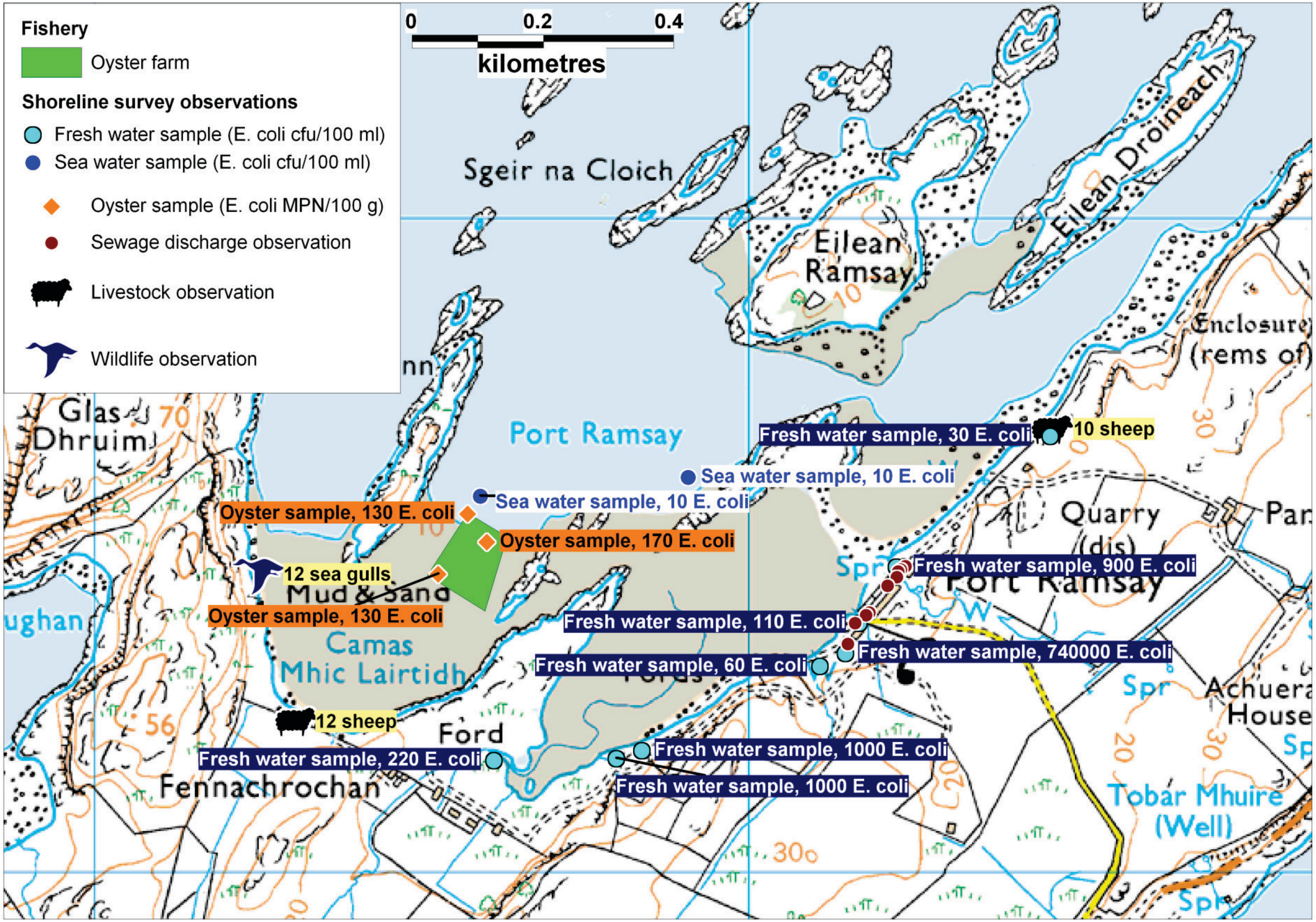

Figure 15.1 Summary of shoreline survey findings for Loch Linnhe

16. Overall Assessment

Human sewage impacts

The population on the island of Lismore is small but a proportion of it is concentrated in Port Ramsay on the eastern side of the bay containing the fishery. Most of the potential sewage contamination will arise from that location: one stream sampled during the shoreline survey gave a result of 740,000 *E. coli* cuf/100 ml indicating probable contamination from nearby septic tanks. There may also be a contribution from a small number of discharges located in the south-east corner of the bay: a septic tank discharge to water consented at that location may have contributed to the moderate *E. coli* loading calculated for a stream at that location. Some faecal contributions may also arise from boats moored in the bay.

Agricultural impacts

Agricultural census data was only available for a parish that covered part of the mainland as well as the whole island. The only information relevant to the fishery was therefore that obtained during the shoreline survey. This identified small numbers of animals to the east and south of the oyster farm. An area of improved grassland identified on the land cover map was also located to the south of the farm and this was the approximate location of a proportion of the observed livestock. Therefore, the main potential impacts from livestock, although small, will be from the south. There may be an additional contribution from east of the shellfishery.

Wildlife impacts

Little information was available for wildlife apart from seabirds. With respect to these, any spatial differences in the extent of contamination would be expected to be associated with a greater input from the nesting and roosting sites to the north-east of the bay.

Seasonal variation

Tourism is expected to be greatest in the summer months and would increase the amount of sewage entering the eastern side of the bay. The spring to autumn period is also the time when farm animal numbers will be highest. Spring and summer will be the peak period for most nesting seabirds.

Rivers and streams

All of the streams recorded and sampled during the shoreline survey were located on the eastern or south-eastern side of the bay. *E. coli* loadings, where these could be calculated, ranged from low to moderate. Possible septic tank contributions to two of the streams were identified above. The contributions from this source would therefore be expected to be greatest on the eastern side of the fishery. Loadings would be expected to be higher after heavy rain. A weak correlation was seen between oyster *E. coli* results and rainfall over the 7 days preceding sampling, but no significant correlation was seen with rainfall over the preceding 2 days. There was also no significant correlation between the *E. coli* results and the salinity at the time of sampling.

Bathymetry and hydrodynamics

Most of the bay is shallow and there are significant drying areas, including around the oyster farm and Port Ramsay. The amount of dilution of contamination arising in the locality will be small. Currents in the area are weak although they are likely to be higher over the drying areas during flood and ebb tides and in the channels between the islands. Contamination arising from sources to the east of the oyster farm will be taken towards the trestles on a flood tide whereas that arising from sources immediately to the south of the farm will be taken towards the trestles on an ebb tide. However, no significant correlation was seen between spring/neap or high/low tidal cycle and *E. coli* in the oysters.

Temporal and geographical patterns of sampling results

No marked changes have been seen in the general level of *E. coli* results in the oysters over the years. A significant difference was seen with season, with results being highest in the summer: this concurred with the results of SEPA faecal coliform monitoring of mussels which showed highest results in the second and third quarters. Six out of the seven results >1,000 *E. coli* MPN/100 g occurred during the period June to September and both results <4,600 *E. coli* MPN/100 g occurred during June.

Many of the samples from the routine monitoring programme had been recorded against the nominal RMP. Where actual sampling locations were recorded, these fell into two clusters, one around high water mark and one around the low water mark. There were no significant differences in results between the two clusters. The SEPA wild mussel monitoring point, located approximately 300 m from the present oyster trestles, showed faecal coliform results of the same order as the *E. coli* results in the oysters.

During the shoreline survey, oyster samples were taken from three locations on the trestles. They gave very similar results ranging between 130 *E. coli* MPN/100 g and 170 *E. coli* MPN/100 g. Two seawater samples were taken during the shoreline survey, both from locations a short distance to the north of he trestles, and these gave very low results of 10 *E. coli* MPN/100 ml. These samples were taken at low spring tide.

Conclusions

Most potential sources of contamination in the area lie to the east of the oyster farm and would be expected to impact on it during the flood tide. Some direct run-off containing diffuse pollution may arise to the south of the farm and would impact mainly on the ebbing tide.

17. Recommendations

Production area

The recommended production area is: "The area bounded by lines drawn between NM 8723 4603 to NM 8780 4603 and between NM 8780 4603 and NM 8780 4546 and extending to MHWS".

This area covers the present oyster farm and both CE leases, including the one in which there is potential interest in developing a mussel site, while excluding identified sources of contamination on the eastern side of the bay.

RMP

The recommended RMP is at NM 8761 4548. This is located on the eastern side of the present area of trestles and should reflect contamination arising from the identified sources on the eastern side of the bay.

Tolerance

Given that the samples will be hand-picked, the recommended tolerance is 10 m. If stock of sufficient size for sampling will not be present at the identified location for a period of time, bagged stock should be placed at that point. The bagged stock should be at the RMP for at least two weeks prior to sampling in order that the animals equilibrate to the water quality at that point.

Frequency

Given the seasonal variability, the recommended frequency for ongoing monitoring is monthly.

Depth of sampling

Not applicable, as the samples will be hand-picked from poches on the trestles.

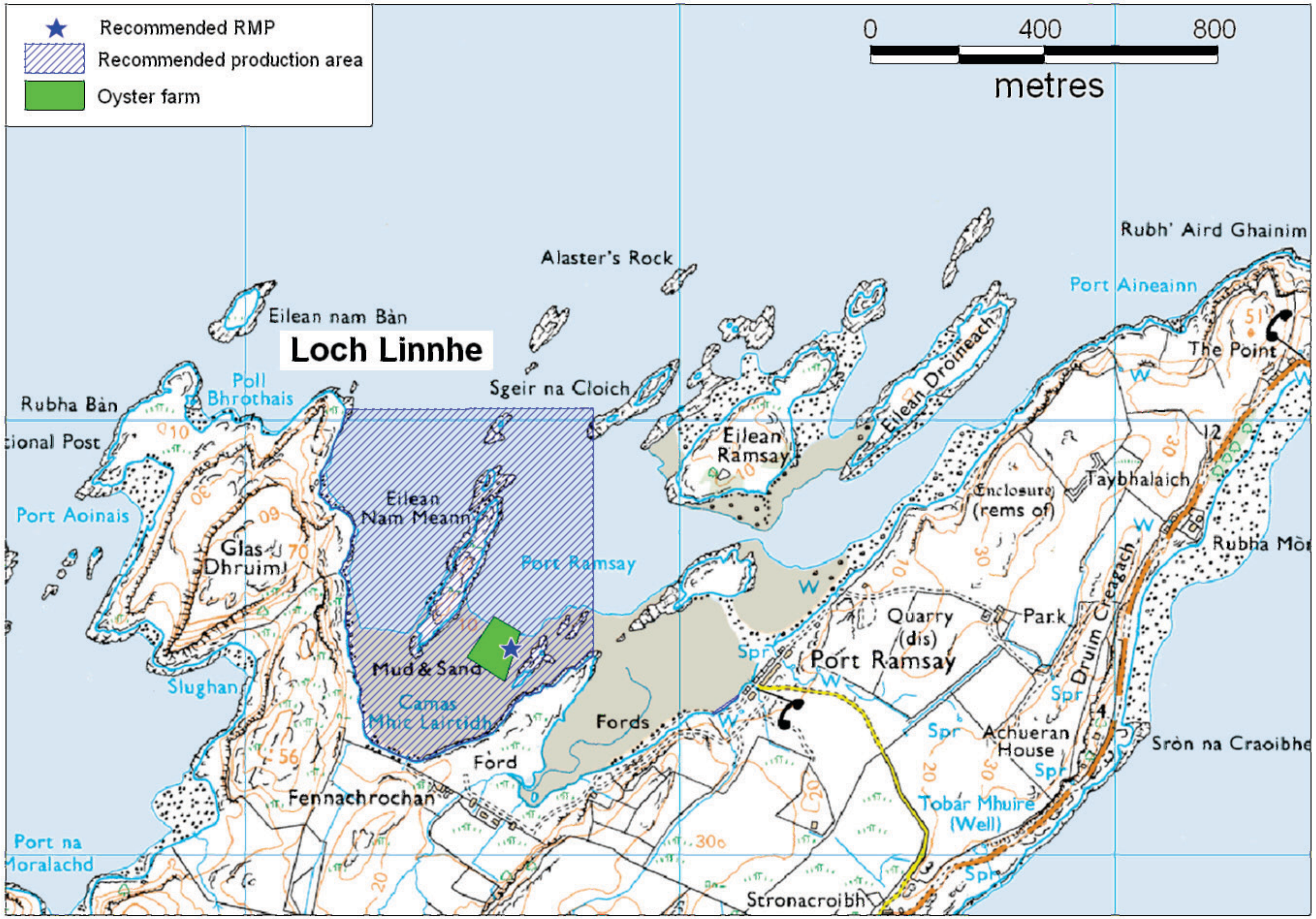

Figure 17.1 Map of recommendations at Loch Linnhe

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19. List of Figures and Tables

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Sampling Plan for Loch Linnhe

PRODUCTION AREA	Loch Linnhe
SITE NAME	Loch Linnhe
SIN	AB 172 047 13
SPECIES	Pacific oysters
TYPE OF FISHERY	Trestle
NGR OF RMP	NM 8761 4548
EAST	187610
NORTH	745480
TOLERANCE (M)	10
DEPTH (M)	N/A
METHOD OF SAMPLING	Hand-picked
FREQUENCY OF SAMPLING	Monthly
LOCAL AUTHORITY	Argyll & Bute Council
AUTHORISED SAMPLER(S)	Christine McLachlan William MacQuarrie Ewan McDougall Donald Campbell
LOCAL AUTHORITY LIAISON OFFICER	Christine McLachlan

Table of Proposed Boundaries and RMPs

PRODUCTION AREA	Loch Linnhe
SPECIES	Pacific oysters
SIN	AB 172 047 13
EXISTING BOUNDARY	Defined as the area bounded by lines drawn between NM 8948 4634 to NM 8860 4770 (Cuilean Rock) to NM 8470 4670 to NM 8460 4264.
EXISTING RMP	NM 876 455
RECOMMENDED BOUNDARY	The area bounded by lines drawn between NM 8723 4603 to NM 8780 4603 and between NM 8780 4603 and NM 8780 4546 and extending to MHWS
RECOMMENDED RMP	NM 8761 4548
COMMENTS	The production area has been reduced in size. The RMP has been moved slightly and redefined to 10 m accuracy.

Geology and Soils Assessment

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 it's 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 50-170kg. 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.

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Tables of Typical Faecal Bacteria Concentrations

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

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

Where appropriate, *E. coli* data was log transformed prior to statistical tests.

Section 11.3 T-test comparison of results by cluster

Two-Sample T-Test and CI: Log EC, High/low

```
Two-sample T for Log EC

High/low   N   Mean  StDev  SE Mean
High      17  2.146  0.812     0.20
Low       19  1.984  0.605     0.14


Difference = mu (High) - mu (Low)
Estimate for difference:  0.162
95% CI for difference:  (-0.330, 0.655)
T-Test of difference = 0 (vs not =): T-Value = 0.67  P-Value = 0.506  DF =
29
```

Section 11.3 Fisher's exact comparison of proportion of results over 230 MPN/100g by cluster

Tabulated statistics: High/low, >230

```
Rows: High/low   Columns: >230

                <=230      >230   All

High               13         4    17
Low                13         6    19
All                26        10    36

Cell Contents:      Count

Fisher's exact test: P-Value =  0.716925
```

Section 11.5 One way ANOVA comparison of *E. coli* results by season

```
Source  DF      SS     MS     F      P
Season   3   6.352  2.117  4.96  0.003
Error   89  37.992  0.427
Total   92  44.344

S = 0.6534   R-Sq = 14.32%   R-Sq(adj) = 11.44%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  --------+---------+---------+---------+-
1      29  1.8300  0.6249     (------*------)
2      23  2.4540  0.8463                     (-------*-------)
3      24  2.0358  0.5180           (------*-------)
4      17  1.7806  0.5662  (--------*--------)
                           --------+---------+---------+---------+-
                                1.75      2.10      2.45      2.80

Pooled StDev = 0.6534
```

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

Individual confidence level = 98.96%


Season = 1 subtracted from:

Season    Lower   Center   Upper  -------+---------+---------+---------+--
2        0.1466   0.6239  1.1012                     (------*------)
3       -0.2659   0.2058  0.6775               (------*------)
4       -0.5716  -0.0495  0.4727           (------*-------)
                                  -------+---------+---------+---------+--
                                      -0.70      0.00      0.70      1.40


Season = 2 subtracted from:

Season    Lower   Center    Upper  -------+---------+---------+---------+--
3       -0.9169  -0.4181   0.0807      (------*------)
4       -1.2201  -0.6734  -0.1267  (------*-------)
                                   -------+---------+---------+---------+--
                                       -0.70      0.00      0.70      1.40


Season = 3 subtracted from:

Season    Lower   Center   Upper  -------+---------+---------+---------+--
4       -0.7971  -0.2553  0.2866        (------*-------)
                                  -------+---------+---------+---------+--
                                      -0.70      0.00      0.70      1.40
```

Section 11.6.1 Spearman's rank correlation for *E. coli* result and 2 day rainfall

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = 0.132
```
n=70, p>0.10

Section 11.6.1 Spearman's rank correlation for *E. coli* result and 7 day rainfall

```
Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.204
```
n=70, p<0.05

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the spring/neap cycle

CIRCULAR-LINEAR CORRELATION
Analysis begun: 21 May 2010 13:05:04

Variables (& observations)	r	p
Angles & Linear (93)	0.122	0.262

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the high/low cycle

CIRCULAR-LINEAR CORRELATION
Analysis begun: 14 June 2010 15:09:24

Variables (& observations)	r	p
Angles & Linear (93)	0.103	0.384

Section 11.6.3 Spearman's rank correlation for *E. coli* result and water temperature

```
Pearson correlation of ranked temperature and ranked E coli for temperature
=0.418
n=78, p<0.0005
```

Section 11.6.3 Spearman's rank correlation for *E. coli* result and salinity

```
Pearson correlation of ranked salinity and ranked e coli for salinity = -
0.114
```
n=53, p>0.10

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.

<u>Background processes</u>
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.

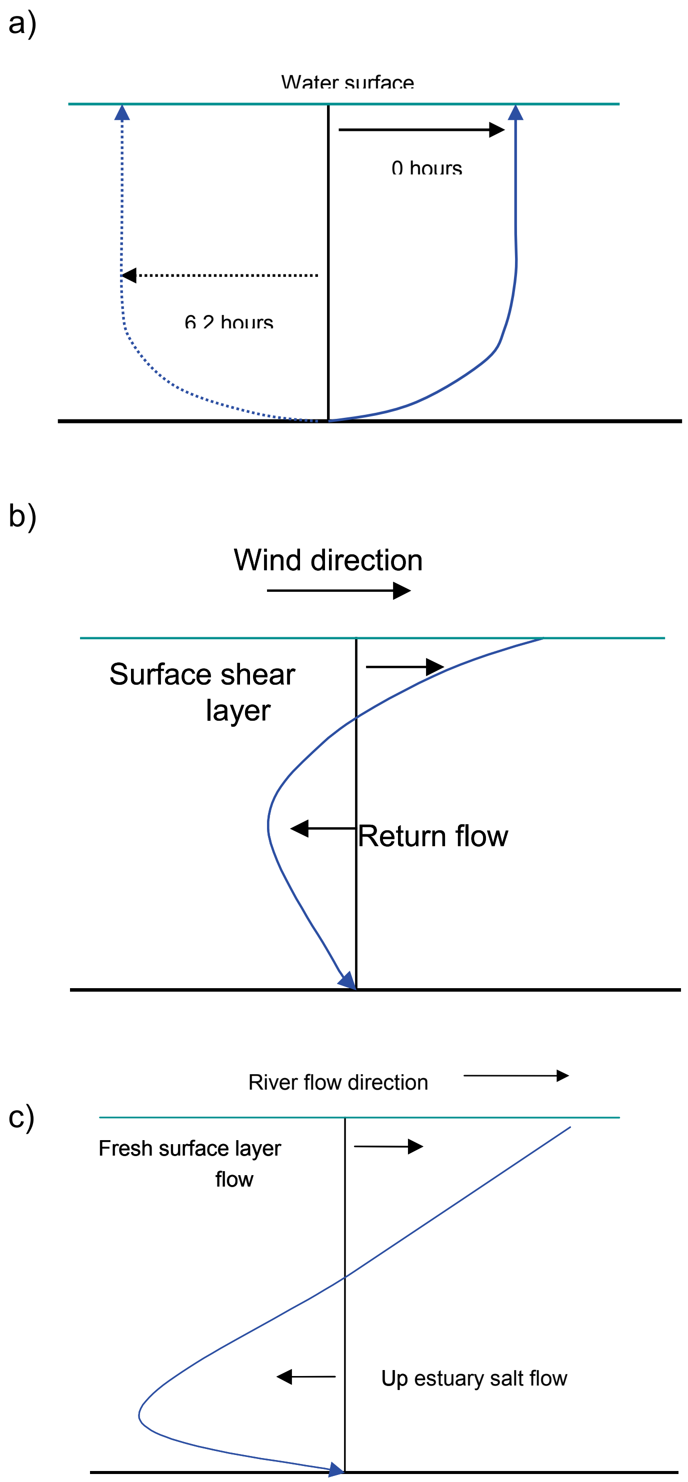

Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

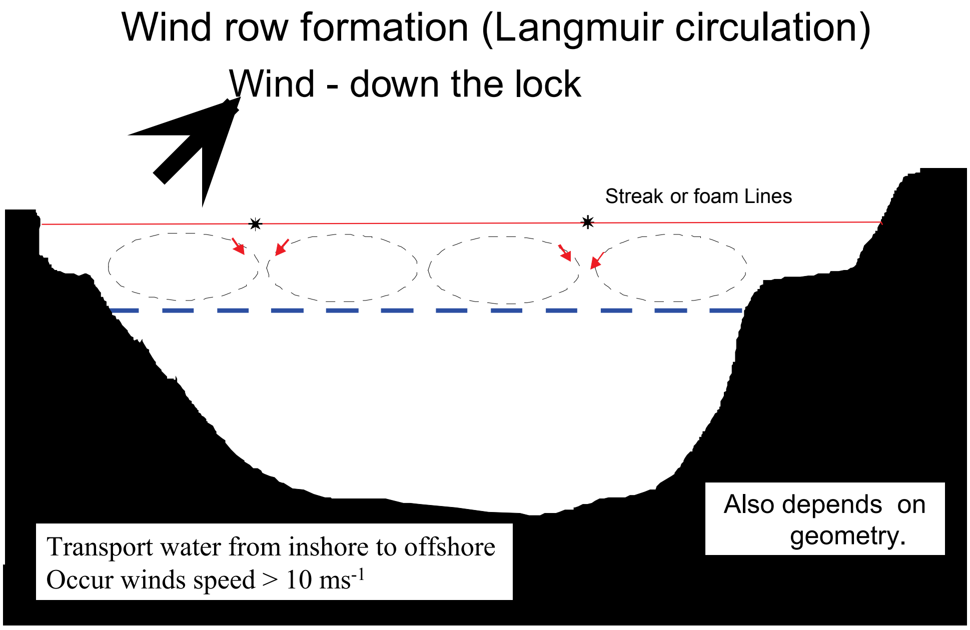

Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

<u>Non-modelling Assessment</u>
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

Production area:	Loch Linnhe
Site name:	Loch Linnhe (AB 172 047 13)
Species:	Pacific oysters
Harvester:	Alan MacFadyen
Local Authority:	Argyll & Bute Council
Status:	Classified

Date Surveyed:	9th September 2010	
Surveyed by:	Jessica Larkham	Cefas
	Ewan McDougall	Argyll & Bute Council
Existing RMP:	NM 876 455	
Area Surveyed:	See Figure 1.	

Weather observations
09/09/2010 – Rain showers at midday, otherwise sunny with some clouds. 13˚C, F2 Light breeze (wind speeds of between 5.6-11 km/hr)

Site Observations

Fishery
There are approximately 250 oyster trestles at the Loch Linnhe fishery. These oyster trestles are situated on an intertidal area in the centre of Port Ramsay. The fishery is situated on a sea bed lease. There is a second seabed lease at Eilean Nam Meann, where the harvester would like to place a mussel raft on a trial basis, in the near future.

Sewage/Faecal Sources
During the shoreline survey nine septic tanks and three outfall pipes were observed on the far eastern shoreline, close to the row of cottages and holiday homes. Only one of the outfall pipes was flowing at the time of the shoreline survey. The septic tanks not associated with outfall pipes discharged to soakaway.

Seasonal Population
There is a daily passenger ferry from Port Appin to Lismore and a small daily car ferry from Oban to Lismore. There is a cafe and museum on the island and visitors can rent bikes. There are 3 guest houses on the island and 9 self catering cottages. Visitor numbers to the island are expected to be higher in the summer months.

Boats/Shipping
There is a daily passenger ferry from Port Appin to Lismore and a small daily car ferry from Oban to Lismore. During the shoreline survey, three pleasure yachts were observed moored adjacent to the cottages and holiday homes on the eastern shoreline of the fishery. There was also a fishing boat and a larger pleasure yacht moored on the western side of the fishery.

Land Use
The land cover surrounding the Loch Linnhe fishery is mainly rough grassland with some patches of woodland.

Wildlife/Birds
Approximately 12 sea gulls were observed on the western shoreline of the Loch Linnhe fishery during the shoreline survey.

Livestock
During the shoreline survey 10 sheep were observed fenced off in a field on the far eastern shoreline. A further 12 sheep were observed in a fenced field, next to a house on the far western shoreline of the fishery.

Recorded observations apply to the date of survey only. Animal numbers were recorded on the day from the observer's point of view. This does not necessarily equate to total numbers present as natural features may obscure individuals and small groups of animals from view.

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 bay.

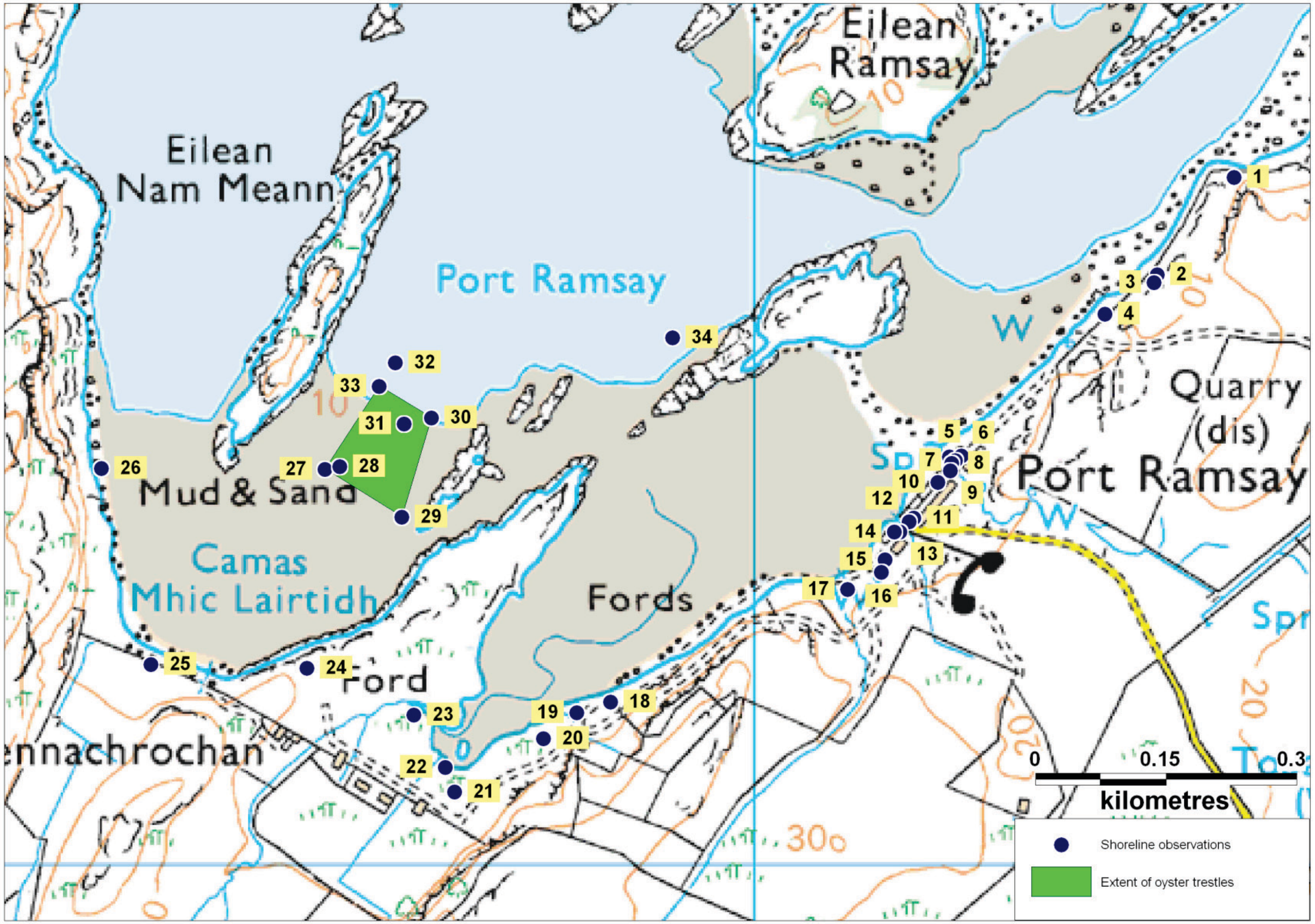

Figure 1. Shoreline observations at Loch Linnhe

Table 1. Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
1	09/09/2010	11:02	NM 88553 45789	188553	745789	Figure 4		Northern section of shoreline inaccessible due to dense foliage and steep cliffs
2	09/09/2010	11:06	NM 88465 45677	188465	745677	Figure 5		Approximately, 10 sheep in field next to shoreline, fenced off
3	09/09/2010	11:07	NM 88461 45668	188461	745668	Figure 6	LINNHE FW1	Stream running through the field of sheep onto shoreline, W 0.40 m, D 0.03 m, Flow 0.149/0.143 m/s. Location of fresh water sample 1 (LINNHE FW 1)
4	09/09/2010	11:15	NM 88405 45632	188405	745632	Figure 7		Pier, 3 yachts moored in the bay
5	09/09/2010	11:22	NM 88226 45468	188226	745468	Figure 8	LINNHE FW2	Stream running down from houses (mainly holiday cottages), W 0.65 m, D 0.05 m, Flow 0.199/0.199 m/s. Location of fresh water sample 2 (LINNHE FW2)
6	09/09/2010	11:26	NM 88240 45469	188240	745469	Figure 9		Septic tank, smells of sewage, no sign of outfall pipe
7	09/09/2010	11:27	NM 88233 45464	188233	745464	Figure 10		Septic tank, no sign of outfall pipe
8	09/09/2010	11:27	NM 88229 45461	188229	745461	Figure 11		Septic tank, no sign of outfall pipe
9	09/09/2010	11:30	NM 88227 45452	188227	745452	Figure 12		Outfall pipe flowing into stream, previously sampled (LINNHE FW2). Pipe flowing at time of observation.
10	09/09/2010	11:33	NM 88213 45439	188213	745439	Figure 13		Septic tank, no sign of outfall pipe
11	09/09/2010	11:35	NM 88185 45398	188185	745398	Figure 14		Two septic tanks, no sign of outfall pipe
12	09/09/2010	11:36	NM 88180 45394	188180	745394	Figure 15		Septic tank and pipe but no flow
13	09/09/2010	11:37	NM 88169 45382	188169	745382	Figure 16	LINNHE FW3	Stream, W 0.40 m, D 0.04 m, Flow 0.002/0.006 m/s. Location of fresh water sample 3 (LINNHE FW3)
14	09/09/2010	11:42	NM 88163 45382	188163	745382	Figure 17		Blue pipe, purpose not known, could not find the end
15	09/09/2010	11:44	NM 88152 45350	188152	745350			Two septic tanks, no sign of outfall pipes. Smells of sewage.
16	09/09/2010	11:50	NM 88148 45336	188148	745336	Figures 18 & 19	LINNHE FW4	Stream flowing down from previous septic tanks. Lots of sewage fungus and strong smell of sewage. Not enough flow to measure. Location of fresh water sample 4 (LINNHE FW4)
17	09/09/2010	11:59	NM 88109 45316	188109	745316	Figure 20	LINNHE FW5	Stream, W 0.80 m, D 0.10 m, Flow 0.025/0.033 m/s. Location of fresh water sample 5 (LINNHE FW5)
18	09/09/2010	12:10	NM 87837 45187	187837	745187	Figure 21	LINNHE FW6	Small stream, too small to measure flow. Location of fresh water sample 6 (LINNHE FW6)
19	09/09/2010	12:14	NM 87798 45175	187798	745175	Figure 22	LINNHE FW7	Stream, smells of sewage, sewage fungus present. Too small to measure flow. Location of fresh water sample 7 (LINNHE FW7)
20	09/09/2010	12:20	NM 87760 45145	187760	745145			Small burn
21	09/09/2010	12:23	NM 87658 45084	187658	745084			Small burn, 8 houses at the end of it
22	09/09/2010	12:25	NM 87647 45112	187647	745112			Small burn
23	09/09/2010	12:28	NM 87611 45172	187611	745172	Figure 23	LINNHE FW8	Stream running into bay, W 0.50 m, D 0.50 m, Flow 0.218/0.278 m/s. Location of fresh

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
								water sample 8 (LINNHE FW8)
24	09/09/2010	12:37	NM 87488 45226	187488	745226	Figure 24		Wild mussels growing on shoreline, also a large number of cockles on the beach
25	09/09/2010	12:44	NM 87309 45230	187309	745230	Figure 25		12 sheep fenced off in field next to a house and adjacent to the shoreline
26	09/09/2010	12:50	NM 87252 45455	187252	745455			12 gulls
27	09/09/2010	12:55	NM 87509 45454	187509	745454	Figure 26		Corner of oyster trestle site. (Approximately 250 trestles in total)
28	09/09/2010	12:58	NM 87526 45457	187526	745457		LINNHE OYSTER1	Location of oyster sample 1 (LINNHE OYSTER1)
29	09/09/2010	13:07	NM 87597 45399	187597	745399			Corner of oyster trestle site
30	09/09/2010	13:09	NM 87631 45513	187631	745513			Corner of oyster trestle site
31	09/09/2010	13:11	NM 87600 45506	187600	745506		LINNHE OYSTER3, LINNHE NORO	Location of RMP, oyster sample 3 (LINNHE OYSTER3) and norovirus oyster sample (LINNHE NORO)
32	09/09/2010	13:20	NM 87590 45576	187590	745576		LINNHE SW1	Location of sea water sample 1 (LINNHE SW1)
33	09/09/2010	13:22	NM 87571 45549	187571	745549		LINNHE OYSTER2	Location of oyster sample 2 (LINNHE OYSTER2) Corner of oyster trestle site
34	09/09/2010	13:33	NM 87908 45605	187908	745605		LINNHE SW2	Location of sea water sample 2 (LINNHE SW2)

Photos referenced in the table can be found attached as Figures 4-26.

Sampling
Water and shellfish samples were collected at sites marked on the map. Bacteriology results follow in Tables 2 and 3.

Samples of seawater were tested for salinity by the laboratory using a salinity meter under controlled conditions. These results are shown in Table 2, given in units of grams salt per litre of water. This is the same as ppt.

Table 2. Water Sample Results

No.	Date sampled	Sample	Grid Ref	Type	*E. coli* (cfu/100ml)	Salinity (g/L)
1	09/09/2010	LINNHEFW1	NM 88461 45668	Fresh water	30	
2	09/09/2010	LINNHEFW2	NM 88226 45468	Fresh water	900	
3	09/09/2010	LINNHEFW3	NM 88169 45382	Fresh water	110	
4	09/09/2010	LINNHEFW4	NM 88148 45336	Fresh water	740000	
5	09/09/2010	LINNHEFW5	NM 88109 45316	Fresh water	60	
6	09/09/2010	LINNHEFW6	NM 87837 45187	Fresh water	1000	
7	09/09/2010	LINNHEFW7	NM 87798 45175	Fresh water	1000	
8	09/09/2010	LINNHEFW8	NM 87611 45172	Fresh water	220	
9	09/09/2010	LINNHESW1	NM 87590 45576	Sea water	10	34.9
10	09/09/2010	LINNHESW2	NM 87908 45605	Sea water	10	33.2

Table 3. Shellfish Sample Results

No.	Date sampled	Sample	Grid Ref	Type	*E. coli* (MPN/100 g)
1	09/09/2010	LINNHE OYSTER1	NM 87526 45457	Pacific oysters	130
2	09/09/2010	LINNHE OYSTER2	NM 87571 45549	Pacific oysters	130
3	09/09/2010	LINNHE OYSTER3	NM 87600 45506	Pacific oysters	170

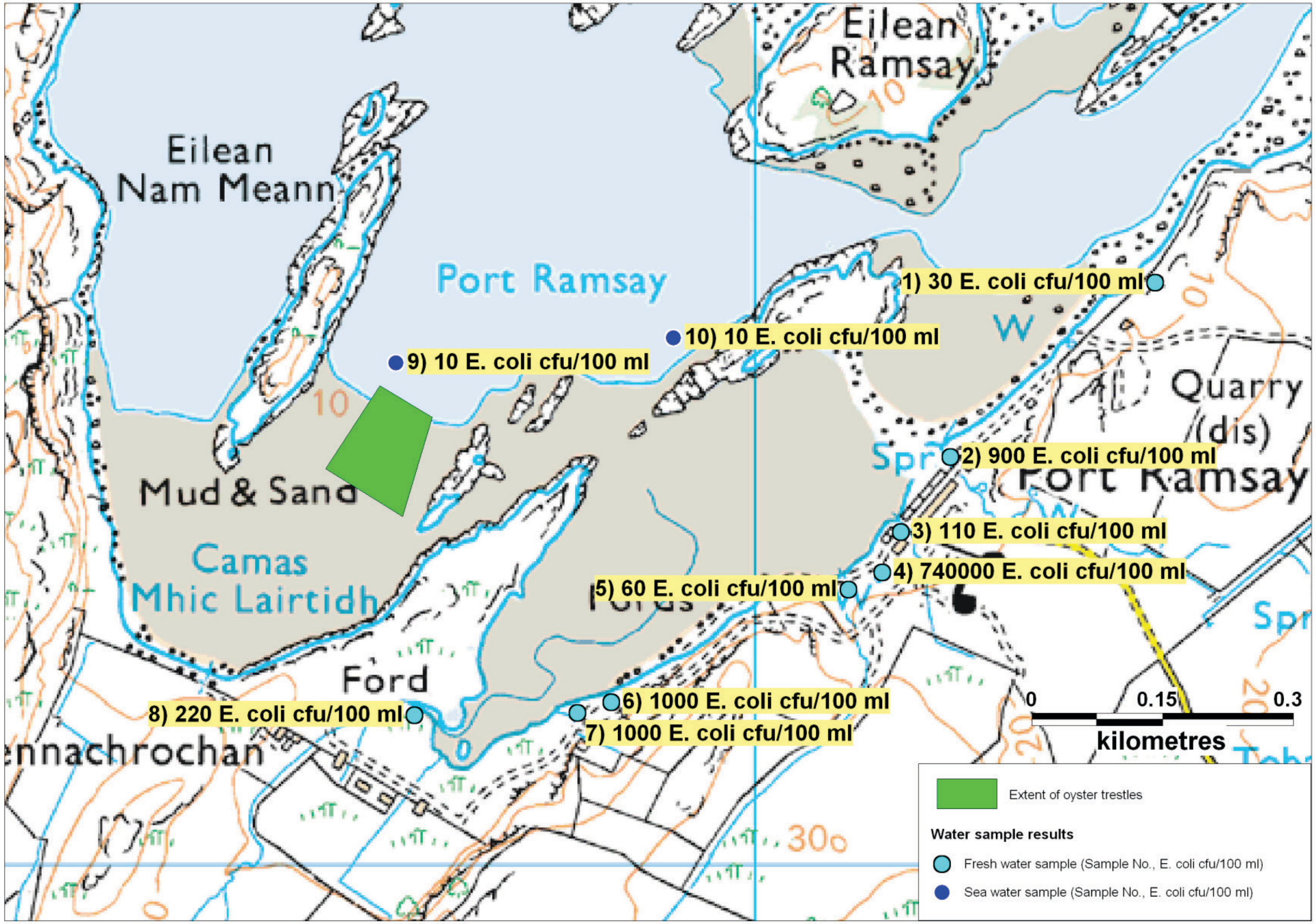

Figure 2. Water sample results

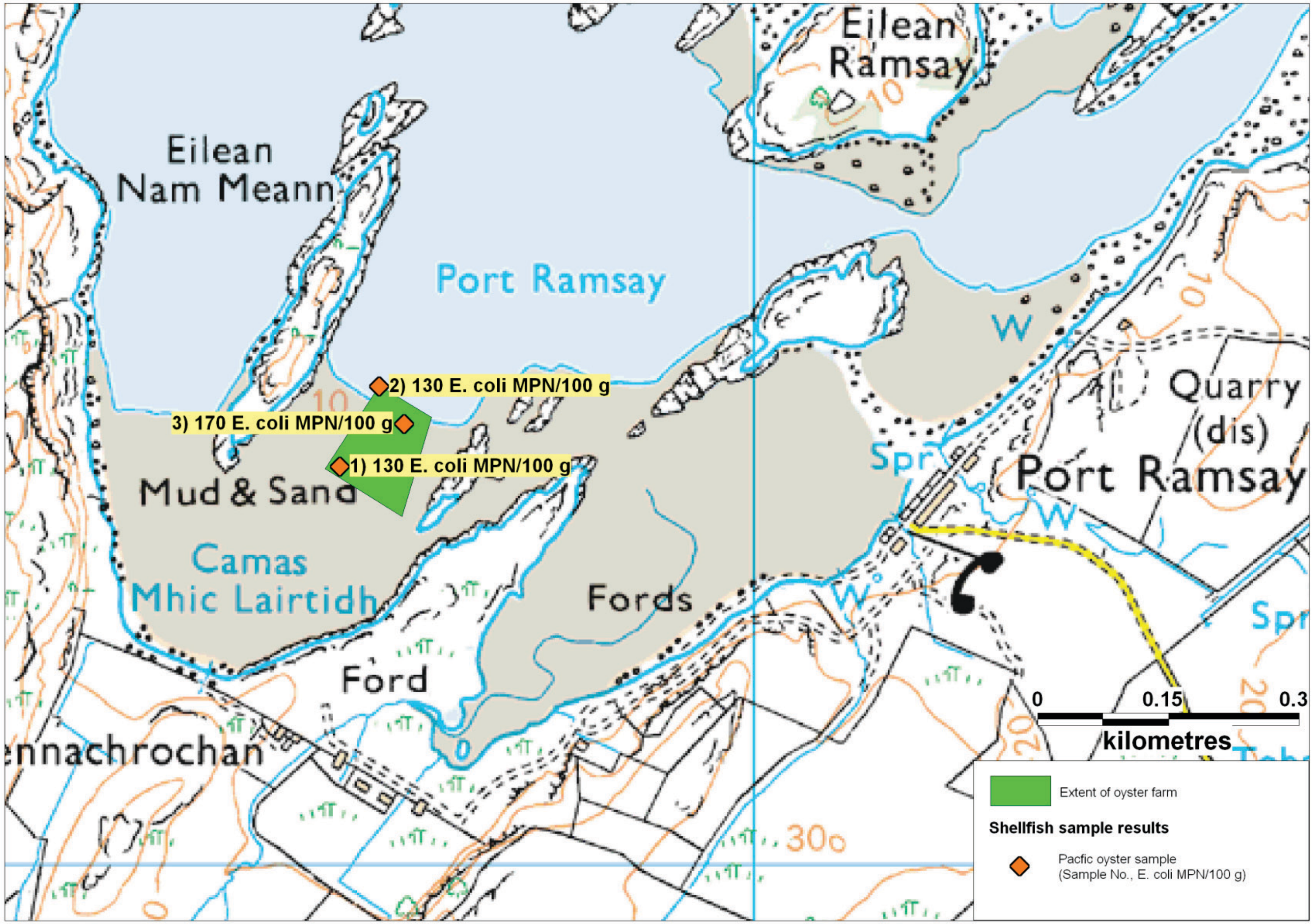

Figure 3. Shellfish sample results

Photographs

Figure 4. Northern section of shoreline inaccessible due to dense foliage and steep cliffs

Figure 5. Approximately 10 sheep in field next to shoreline, fenced off

Figure 6. Stream running through field with sheep in

Figure 7. Three yachts moored in the bay

Figure 8. Stream running down from houses, location of fresh water sample 1 (LINNHE FW1)

Figure 9. Septic tank, no sign of outfall pipe

Figure 10. Septic tank, no sign of outfall pipe

Figure 11. Septic tank, no sign of outfall pipe

Figure 12. Outfall pipe flowing into stream previously sampled (LINNHE FW2)

Figure 13. Septic tank, no sign of outfall pipe

Figure 14. Two septic tanks, no sign of outfall pipes

Figure 15. Septic tank and pipe, no flow

Figure 16. Stream, location of fresh water sample 3 (LINNHE FW3)

Figure 17. Blue pipe, purpose not known, could not locate end

Figure 18. Stream, location of fresh water sample 4 (LINHHE FW4) Smells of sewage and lots of sewage fungus present

Figure 19. Sewage fungus in above stream (location of LINNHE FW4)

Figure 20. Stream, location of fresh water sample 5 (LINNHE FW5)

Figure 21. Stream, location of fresh water sample 6 (LINNHE FW6)

Figure 22. Stream, location of fresh water sample 7 (LINNHE FW7)

Figure 23. Stream, location of fresh water sample 8 (LINNHE FW8)

Figure 24. Wild mussels growing on the shoreline

Figure 25. Approximately 12 sheep in field next to a house and adjacent to the shoreline

Figure 26. Oyster trestle site

Norovirus Testing Summary

Loch Linnhe

Oyster samples taken from the oyster trestles at Loch Linnhe were submitted for Norovirus analysis quarterly from September 2010. Results to date are summarised in the table below. Sample results for June 2011 were not yet available at time of reporting.

Ref No.	Date	NGR	GI	GII
10-401	09/09/2010	NM 8760 4551	not detected	not detected
10-575	06/12/2010	NM 8759 4548	not detected	positive
11-686	21/03/2010	NM 8760 4550	positive	not detected